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An Experimental Study of the Rest Period in Plants

The Winter Rest

FIRST REPORT

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AN EXPERIMENTAL STUDY OF THE REST PERIOD IN PLANTS.

THE WINTER REST: INITIAL REPORT ON THE TREATMENT OF DORMANT WOODY PLANTS FOR FORCING THEM INTO GROWTH.

By W. L. HOWARD, *Professor of Horticulture.*

BRIEF SUMMARY

(1) Plants rest in winter, and they also have rest periods in summer, but all of these forms of rest are caused by unfavorable external conditions.

(2) Outward conditions determine both the time of occurrence and the degree of intensity of the period of rest. If unfavorable conditions, such as cold or drought, occur at regular intervals, a plant readily adapts itself to the new demands and the rest becomes a habit which may continue to be repeated automatically for a longer or shorter period of time.

(3) The habit of rest induced by outward conditions is often very strongly fixed and is apparently transmissible.

(4) There are many ways of arousing plants from a resting state (especially the winter rest), the principal ones known being the raising of the temperature, the use of gases and vapors, by freezing, and through desiccation.

(5) By means of careful cultural methods plants may be caused to omit their ordinary habit of resting and grow continuously.

(6) There are numerous theories of the workings of some of the special treatments, such as ether and chloroform, freezing and drying, and how they produce growth, but it is probable that none of them exert any specific action.

Introduction

The work done by the Missouri Experiment Station[1] on the hardiness of the peach, covering the past several years, shows in emphatic manner that, fundamentally, the matter of hardiness (with this fruit at least) is intimately associated with the rest period. In order, therefore, to arrive at a better understanding of this aspect of

[1] Whitten, J. C., Winter protection of the peach. Bul. No. 38, Mo. Exp. Sta. 1897; and Chandler, W. H., The hardiness of the peach: Winter killing of the buds as influenced by previous treatment. Bul. No. 74, Mo. Exp. Sta. 1907.

the subject of hardiness, it was deemed necessary to make a careful study of the nature and principles of the rest period of plants in general.

By "rest period" or "dormant period" is meant the time of rest, or period when plants do not grow. This, as a rule, corresponds to the winter season of the year with most of our common woody plants that grow outside in this climate. It is a matter of common experience that many of the plants that rest or remain inactive during the winter, will begin to grow in a short time if taken into a warm room, even in midwinter. Some will even begin to grow outside during the winter after the weather has been mild for a few days. On the other hand, there are many plants that will make no growth whatever until near spring, even though they are taken into a warm, moist room and kept there. These experiences led to the popular belief that there are many plants which have such profound resting periods that they cannot be made to grow until at or near the normal time for awakening in spring.

In order to learn something of the fundamental nature of the rest period and to test the extent to which plants may be caused to start into growth out of their season, i. e. while dormant, nearly three hundred species of woody plants were examined by bringing them into the greenhouse after they had gone into their resting state, and noting which ones began to grow under the influence of the warmth. As anticipated, it was found that the dormant state varied very greatly with the different species, not only in point of the duration of the rest, but also in the degree of its intensity. The extremes in woody plants are probably represented by two typical cases, viz., *Spiraea sorbifolia* L. and *Fagus sylvatica* L. The former is a plant which appears to have no resting period, seeming to stop growth only when the weather is actually too cold for cell division, while the latter goes dormant in the fall at the approach of cold weather and remains so until the time of settled weather in spring, even though it be brought into a warm, moist room. In short, the *Spiraea* will make an almost continuous growth during the winter when kept inside or, will spring into growth within a day if brought in during the winter, while the *Fagus* will not grow at all during its period of rest through the influence of warmth alone.

Out of the long list experimented with, quite a number were found to be very difficult to awaken from their resting state, even under severe treatment, while others would eventually make some growth merely under the influence of warmth, but would grow much more readily when given special treatment. Experiments were then

inaugurated to test the efficacy of certain treatments for forcing growth.

As a result of extensive studies and experimentation, it is concluded that nearly all of our ordinary woody plants, such as fruit trees, ornamental shrubs, etc., have definite resting periods, that is, that each species, and possibly each variety, has a certain number of days during which it will not grow under natural conditions. These facts have led to the conclusion that a knowledge of the so-called winter rest period of plants, its nature and extent in different kinds and types of plants, is fundamental to the study of many of the practical questions of horticulture.

One practical application of the above principle is that, if, say, in the case of the peach, which is known to have a comparatively short rest period (about six weeks), the trees can be caused to continue growing later in the autumn, that is, go dormant late, they will remain dormant a correspondingly longer time in late winter, and hence not be so liable to injury by freezing after having made a slight growth. Peaches are nearly always killed by reason of their habit of premature growth during warm days in late winter. Every fruit grower knows that there is no danger of growth taking place in early winter, no matter how warm and mild the weather may be, because the trees are then in the midst of their rest period. When fully dormant, peach buds can safely withstand the low temperature of 20 degrees F., but after having made a slight growth, zero weather will nearly always be sufficient to kill them all.

The subject of hardiness, then, in the peach, as well as in other plants, may be found to be intimately associated with the rest period. If it were known definitely that plants have a tendency to grow at unseasonable times by reason of the fact that they have very slight resting periods, or that the resting stage is at an end, we might then set about devising means for regulating the period of dormancy, or, knowing that their habits of growth in this respect cannot be easily changed, of finding means for protecting them.

Another practical advantage resulting from a knowledge of the rest period of plants, together with a practical means for rousing them into growth out of season, is in the commercial forcing of flowering plants and garden vegetables, as practiced by the florist and gardener. Large sums of money are now invested in plants like lilac, deutzia, etc., they being grown especially for forcing purposes in winter. The use of anesthetics (ether and chloroform), as well as freezing and desiccation, in causing these plants to grow quickly and bloom profusely, will undoubtedly soon play a very important part, if indeed they do not supplant other methods of forcing. Vegetables, like rhu-

barb and asparagus, have been forced by the use of anesthetics in a commercial way, to only a comparatively slight extent, although with the improvement in methods of handling, anesthetics and also desiccation and freezing may be used to a much larger extent in this sort of forcing work.

GENERAL REVIEW OF EXPERIMENTS AND RESULTS.

Owing to the very slight amount of experimental data available concerning the dormancy of plants, it was found necessary, at the outset, to test as many species—both trees and shrubs—as possible, to find if they could be made to grow during winter. All the plants used in the main experiments were deciduous species, native to the temperate zone. All of them passed into their usual state of dormancy at the approach of cold weather. This was about the middle of October.

Taking the plants, then, as they occurred under their environment, the first question to be answered was, which ones could be aroused into growth during the early stage of their dormancy, by any means whatsoever. Many, it was known, would grow with comparative ease, merely under the influence of warmth, while there were others that would make no growth whatever under such circumstances. Also some data were available showing that certain treatments—particularly with ether and chloroform, were effective in hastening growth in the cases of the few plants that have been tried, but to what extent these or any other treatments would hasten growth or, produce growth at all, with the great majority of plants, was practically unknown.

The investigation was begun in the fall of 1905 at the Botanical Institute of the University, at Halle, Germany. The Botanic Garden there contained a good collection of trees and shrubs growing under natural conditions for the work. Not only was the collection of the German and other European species large, but it included many forms from the United States and other countries, that were especially useful for the experiment. These plants being of wide distribution, offered special opportunity for comparing results obtained with the results of similar tests carried on at the Missouri Experiment Station the following year—1906-7.

From the outset positive results were quickly forthcoming and, for the most part, the main question of the investigation was answered. The first list of 283 species was not treated, the plants being merely brought into the warm, moist greenhouse, where they were allowed to stay until they either grew or died. The list mentioned comprised two collections, one made in November and the other in

January. Of the first collection over half grew and from the last 86 per cent grew.

After this preliminary investigation special lists were made up to be treated for forcing growth. As a rule, those species that had been found to grow easily without treatment were omitted. The principal treatments employed were ether, freezing, drying, and confining in a moist dark-chamber. These treatments were used both singly and in combination. There were three main experiments and several more or less isolated miscellaneous tests.

In all, during the three main experiments, between November 17 and December 24, 1905 (Tables III, VI and IX), 133 different species were treated and all but 14 grew. By various means employed in some of the miscellaneous tests, 7 out of the 14 were caused to grow, so that growth was secured in January or earlier, from 126 species. Of the remaining 7, *Liriodendron tulipifera* and *Fagus sylvatica* grew in February, and *Carya aquatica, C. porcina, Juglans regia, Quercus alba* and *Q. coccinea,* in March.

It should be noted also that of the 283 species that were merely brought into the greenhouse (not treated), 211 grew in January or earlier, 36 by February or before, and the remaining 36 by March or earlier.

The real importance of this information lies not so much in the matter of whether the plants grew with or without treatment, as in the fact that they would grow at all by mid-winter or before. *This shows conclusively, that the great majority of species, indigenous to temperate climates, do not have a firmly fixed winter resting period from which they cannot be awakened.*

It is of interest that more than half of the entire list of kinds grew easily inside of two weeks, without treatment. The remaining 140 or 150 forms, however, awakened with more or less difficulty. Seventy-two of the kinds showed much resistance to growth even in late winter (February) and 36 of the number were very resistant and would not grow (untreated) until the approach of spring (March).

The species found most difficult to force were *Carya aquatica, C. porcina, Fagus sylvatica, Fraxinus americana, F. excelsior, F. Ornus, Juglans regia, Liriodendron tulipifera, Quercus alba, Q. coccinea* and *Q. olivaeformis*. Seven of this list with strong resting periods are American species and four of European and Asiatic origin.

Experience in this investigation has shown that there are apparently times when a given species will grow more readily than at other times under treatment, which leads to the belief that if the treatments are repeated at frequent intervals it is highly probable that all of the

species may be forced into growth in early or mid-winter. From the experiments of Klebs[2] we are justified in the opinion that with previous cultural treatment the most resistant forms can be made to grow at any time and perhaps eventually be made to have very short, or light, resting periods, if not to omit them entirely.

DISCUSSION OF THE REST PERIOD.

Since our common plants in nature have a regularly recurring dormant stage, the question arises as to what is the nature of this rest period. Pfeffer[3] has cited Askenasy's experiments with a large number of plants including *Quercus pedunculata, Tilia europea,* and *Castanea vesca,* stating that they and other species would not open their buds before March or April and that some of them required even a longer period of rest. Klebs,[4] however, dissented from this opinion, but the citations given above show the prevalence of the belief that in a great many plants the rest period of winter is long and deep and that it cannot be broken. The experiments of the writer, too, show that such a view is incorrect. The species mentioned by Pfeffer and Askenasy were said not to grow before March or April, but the results of the experiments herein reported show that they will grow from treatments in early December and without treatment in January.

But why do they become dormant? Is it necessary that they cease all growth for a time, or do they do so because they are overtaken by winter? In other words, do the plants voluntarily become dormant or are they forced into that state on account of unfavorable conditions?

The first case would be the result of an inward, strongly fixed, hereditary law, while the other would only occur—if the inherent tendencies of the plants could be followed—when outside conditions brought it about. That the ordinary winter rest is firmly fixed is experimentally disproven but it will be appropriate here to discuss the subject further. Pfeffer believed that there were two forms of rest periods of plants, the one due to inward causes, which he called "autonomic" and the other the result of outward conditions, which (in 1901) he termed "aitionomic." Concerning this view he later discussed[5] the rise and fall of growth in certain plants and his con-

[2] Klebs, Georg, Willkürliche Entwickelungsänderungen bei Pflanzen. pp. 127-137.

[3] Pfeffer, W., Pflanzenphysiologie. Bd. II. 1904. p. 260.

[4] Klebs, Georg, Willkürliche Entwickelungsänderungen bei Pflanzen, p. 129.

[5] Pfeffer, W., Pflanzenphysiologie. Bd. II. 1904. p. 20.

clusions were that, inasmuch as the oscillations occurred during the most uniform outward conditions, they were due to autonomic causes. As the result of years of direct experimenting with *Sempervivum* and other plants, Klebs[6] did not agree with Pfeffer, and in 1905, in discussing the question he declared that, while there was a difference in the kind and degree of variability in plants, and that to a greater or less extent this, as well as all other variations or changes in plants were brought about by the inner conditions, these inner conditions were wholly dependent upon the environment and hence a change in outer conditions, or rather the character of the outer conditions, would determine the changes that take place in the plant.

From his own investigations, and now by the writer's the position taken by Klebs seems very probable,—that all rest periods of vegetation are traceable to one cause, and, that that cause is environment, seems clear.

Returning to the matter of the dormant stage of woody plants, it should be stated that the approach of the rest period is usually preceded by the formation of terminal buds on all growing shoots and (with deciduous plants) the shedding of the leaves. This preparation for winter occurs with great regularity every year in any given place, but there is much good evidence to show that the plants would not become dormant if not compelled to do so by the cold.

In the first place, the large number of species in the writer's experiments in forcing—more than 50 per cent of the number tested—which grew readily when brought into the warm air, shows that the rest was abnormal, and the experiments of Klebs[7] with annual, biennial and perennial herbaceous plants show in conclusive manner the astonishing fact that they not only would not become dormant if not forced to do so by the winter, but they did not require rest.

Although unnecessary, the oft-repeated habit of becoming dormant at a particular time, year after year, exerts a powerful influence upon a plant and even causes the habit to become so firmly fixed as to be transmissible. An example of this is shown in some northern and southern grown forest tree seeds of different species, particularly *Gleditschia triacanthos, Acer negundo,* and *Juglans nigra,* which were sown on the Horticultural Grounds of the Missouri Experiment Station in 1896. At first there were notable differences in the time of leaf-fall and rate of growth between those from the different regions, but after eight or nine years these differences, together with others,

[6] Klebs, Georg, Ueber Variationen der Blüten. p. 297.
[7] Klebs, Georg, Willkürliche Entwickelungsänderungen bei Pflanzen. pp. 129-138.

had adjusted themselves to correspond with their new environment. This example furnishes experimental proof that environment may be much stronger than heredity, i. e. that characters which are so firmly fixed as to be transmitted to the seed can be overcome and changed in a comparatively short time by external conditions. In this connection DeCandolle,[8] writing a hundred years ago, stated that plants from southern climates strive to repeat their normal periodicity, and if the external conditions permit it, develop leaves and flowers at unusual times, but in the progress of a few years, however, they may accommodate themselves to the new conditions and by lengthening their resting period, assume a yearly periodicity corresponding to the changed climate.

Plants are plastic enough to quickly adjust themselves to new conditions, especially when their lives are endangered, while otherwise the change may take place slowly. An illustration of the first case was the southern plants that were taken north and at first winter killed, while a good example of the latter case is the following: Two or three specimens of *Quercus pedunculata,* growing in pots were kept in the greenhouse both summer and winter for two years and they still continued to cease growing in autumn and remain dormant until spring, thus showing that the habit of resting for a long period during winter was strongly fixed. But this strong rest period can be broken, even in its early stage, as is shown in the experiment described on page 80, where apparently, slight freezing was the cause of the growth.

The history of the pot-grown *Quercus pedunculata,* mentioned above, is here of interest. In the autumn of 1904 Professor Klebs planted the acorns in pots, which were kept in the warm greenhouse. The seed soon germinated and the young plants grew vigorously all winter and until the following March, when winter buds were formed and all growth ceased until early summer. This experience is identical with the behavior of the oaks that were forced into growth in winter by freezing and etherizing. (See pp. 23 and 80.)

That the winter rest may be broken readily in a great many species where the habit is strongly fixed has been shown in the experimental data of this report, so that it will now be instructive to notice the experiments of Flammarion[9] and Klebs. In 1891 the former planted a number of acorns of *Quercus robur* in pots and kept them protected from winter conditions for fifteen years, with the

[8] DeCandolle, A., Mémoires présentés par divers savants. t. I. 1806. p. 349.

[9] Flammarion, C., Bul. Mens. de l'Off. de Renseigm. Agric. 6, No. 11, pp. 1327-8.

result that the young trees have changed their habit of growth until they resemble evergreen species, in that the young leaves now appear before the fall of the old ones.

Klebs [10] reported some remarkable results in handling plants to prevent the rest period from taking place. Two typical examples of this work were with *Hyacinthus* and *Ficaria ranunculoides*. The former was caused to grow throughout the summer and flower in September, after having bloomed normally the previous winter. It is the habit of the *Ficaria* to bloom in spring and then the tubers rest throughout the summer and winter until spring again, but by cultivating them in the hotbed and greenhouse they were caused to bloom in winter; then when the plants died down the tubers were again cultivated and by July were once more in bloom.

Regarding these very important results Klebs [11] writes: "In the cases of both the *Hyacinthus* and *Ficaria* it is evident that through the high temperature the inner conditions of the otherwise resting organs were changed so that, on account of the continued favorable conditions, they did not enter the resting period at all, or only partially, and that by further perfecting methods of culture, it will later be possible to bring the majority of plants with inner rest period to an uninterrupted growth."

The foregoing results throw much light upon the subject of the rest period. The experiment last mentioned, with the conclusions reached by the investigator are most important for, if by cultural methods, or other previous preparation, the usual rest period is omitted entirely, or at least much attenuated, then the most refractory species (*Hicoria, Quercus, Fagus,* etc.) may be made to grow throughout the winter (in a greenhouse), or, certainly to be awakened at will. Further investigation on this point will be awaited with interest.

The foregoing statements and examples indicate that the winter rest is a habit induced by unfavorable outward circumstances and that, if those conditions are removed, some species at least while yet under the powerfully acting influence of recent habit, can be induced to grow readily. That outward conditions may profoundly modify the habits of plants was shown in the case of the northern and southern trees which took on characters intermediate between the two extremes.

[10] Klebs, Georg, Willkürliche Entwickelungsänderungen bei Pflanzen. pp. 129-134.

[11] Klebs, Georg, Willkürliche Entwickelungsänderungen bei Pflanzen. p. 137.

In his instructive discussion of the relation of the specific structure of plant organisms to their inner and outer conditions, Klebs,[12] after enumerating the factors which constitute the inner conditions, says, "Everything about a cell, an organ or an entire plant is really determined by the inner condition or specific structure of the cell." Continuing, however, he states further that "the fundamental fact upon which the whole biological inquiry rests is the dependence of the inner conditions upon the environment. All of the above mentioned conditions (water content, osmotic pressure, etc.) are variable; but their variability has necessarily a close connection with the environment." Pursuing the subject further, the same author sums up the matter in a single sentence and in so doing really sounds the keynote to the whole subject of variation as brought about by environment. *"It is only necessary,"* said he, *"to influence the cell at the precise time when it is about to assume its definite specific structure or characteristics."*

It is true that the immediate preparation for the winter rest—formation of terminal buds and leaf-fall—comes from within, but all of this is the result of habits formed from oft-repeated occurrences, which are the influencing outward conditions, such as the coming of winter.

The rest period is referred to by Drude and Naumann,[13] Johannsen,[14] and others, as being due to inner causes, but it would evidently be more correct to say that it is caused by outward conditions. The case of the oaks becoming dormant and remaining so in the warm greenhouse may seem to refute this, but when it is remembered that others yielded to treatment and made a luxuriant growth in an early stage of their dormancy, the true nature of the rest period appears to be established.

Besides the winter rest, such as has just been described, there is yet another kind of rest which occurs in summer. There are two forms of summer rest; that caused by drought or injury, and that that is manifested by *Crocus, Anemone, Ficaria,* etc. An example of the first case is furnished by a young elm tree (*Ulmus americana*) which was planted on the Horticultural Grounds of the Missouri Experiment Station in the fall of 1903. The following season the tree made a good growth up to the beginning of August, at which time a drought set in and continued with such severity that it ceased to

[12] Klebs, Georg, Ueber Variationen der Blüten. 1905. pp. 293-4.

[13] Drude, O., Naumann, A., u. Ledien, F., Ueber die von Ostern 1901 bis 1902 im Königl. Botanischen Garten zu Dresden angestellten, den Gartenbau betreffenden Versuche, etc. p. 2.

[14] Johannsen, W., Das Aetherverfahren beim Frühtreiben mit besonderer Berücksichtigung der Fliedertreiberei. 1906. p. 10.

grow and by September first had formed strong terminal buds, as well as plump, well formed axillary buds, and finally shed its leaves. Heavy rains coming on later, the rest was broken and the buds began to grow. The terminal buds grew and the shoots elongated several inches and in some instances the side buds also grew. Growth continued throughout October and until far into November, the autumn being late, when the leaves fell and the entire tree became dormant in a normal manner, another crop of plump buds being formed in the axils of all the new leaves. It was interesting to note that the twigs showed the usual rings at the points where the second growth began, these being identical with the usual annual markings of this character. A similar experience is reported by P. Magnus [15] of the abnormal growth of an *Aesculus Hippocastanum* in Berlin during the autumn of 1884 where, through heat, drought and injury by insects, the tree closed its growth, shed its leaves and matured its buds, but grew again later when rainy weather came. He also observed the same phenomena in linden trees.

This is clearly an enforced form of rest, having been forced upon the plants by the unfavorable conditions. It is probable, though, that if they were repeated regularly every year, the habit would eventually become strongly fixed with many species.

Schimper [16] and Volkens [17] corrected the popular idea that all tropical vegetation is evergreen. These authors report that at certain times of the year many tropical trees shed their leaves and pass into a state of rest.

Plants apparently have several rest periods. In temperate regions it is difficult to observe this character owing to the disturbing factor of winter. In such regions the well marked seasons determine the time of rest and activity of nearly all forms grown in the open. In the tropics, however, especially in regions of abundant and well distributed rainfall, we might expect to find a true state of affairs as regards the manifestation of a well marked periodicity in plants. Concerning this phenomenon Schimper [18] reports that his observations in tropical districts, with abundance of rain at all seasons of the year, have taught him that there, also, vital processes in plants exhibit a rythmic alternation of periods of repose and activity. This opinion, he declared, however, was dependent upon a conception of rest pe-

[15] Magnus, P., Botanische Mitteilungen. Separatabzug aus den Verhandlungen des Botanischen Vereins der Provinz Brandenburg. XXVI. 1885.

[16] Schimper, A. F. W., Pflanzengeographie auf physiologischer Grundlage. pp. 286 and 370.

[17] Volkens, G., Der Laubwechsel tropischer Bäume. Gartenflora, 52. Jahrg. Heft 22. 1903. pp. 591-598.

[18] Schimper, A. F. W., Plant Geography. Tr. by Fisher, Groom & Balfour. 1903. pp. 241-5.

riods that would differ from the usual one. By this he meant that there are no periods of rest for the vital processes as a whole, but only resting periods for certain functions. He continues: "A plant during its hibernation is by no means inactive. In many trees, starch is converted into oil; the chlorophyll-corpuscles of conifers produce red coloring matter; the epidermis of the leaves of many herbs produces cyanophyll; the roots continue to grow in length; the winter buds, by means of invisible processes, acquire the power of further development, which was lacking in them in the warm season, and so on. On the other hand, repose chiefly prevails as regards the inception, the growth in length and thickness of the shoots, although there are exceptions. Assimilation is weakened, yet suspended only in hard, frosty weather."

The same author states that: "There is therefore in the temperate zones no season of the year that does not tend to set in motion certain functions of plant-life, and to set others at rest. During autumn and winter repose predominates, and during spring and summer activity predominates, so that we may speak of relative seasons of rest and of vegetation, although at no season is either condition actually realized. Tropical plants are just as subject to the periodic alternation of rest and of activity as are those of the cooler and cold zones. Wherever a sharp climatic periodicity prevails the functions of the plant-organism in the tropics also appears to be decidedly influenced by it. Thus dry seasons act like cold ones in many respects. The less marked the periodicity of the climate is, the less dependent upon its influence is the periodicity in the plant. Internal causes are mainly or solely responsible for the alternation of rest and of activity in a nearly uniform climate. Such a rythmic change is, however, never abandoned, for it arises from the nature of the living organism and not from external conditions; its connection with external conditions is a secondary feature—an adaptation."

As to the detailed behavior of the vegetation where heat, cold or dryness do not interfere, he writes these significant words: "In all tropical districts with very weak climatic periodicity, there are *woody plants that shed their leaves at longer or shorter intervals* (*one to six times a year*), *without any connection with the season of the year,* so that trees of one and the same species, under the same external conditions, acquire fresh foliage and shed their leaves at times that do not agree."

Volkens found that while several species shed their leaves, the period of rest was very short, in some instances new leaves beginning to form as soon as the old ones were off. He observed also that some trees have two periods of leaf-fall during the year. He further states that the time of leaf-fall varies with the different species.

While general observations on the behavior of tropical vegetation have disclosed some interesting results, it is evident that it is very necessary that exact experiments should be performed before we can draw any definite conclusions as to the causes of leaf-fall at different times of the year. It must be that there are good reasons for the shedding of the leaves at irregular intervals, which, at present, are unknown. Inasmuch as there is no regularity about the occurrence of the defoliation, it stands to reason that there must be influencing factors that have not yet been noticed. Under conditions of great uniformity as regards warmth and moisture, it would not be at all surprising—indeed might be expected—that very slight causes might influence the plants sufficiently to bring about considerable fluctuations in leaf-fall. However, in the absence of more exact physiological data on tropical vegetation, no final explanation can be given for the phenomena mentioned.

Regarding the other form of summer rest, that of the *Anemone, Crocus, Ficaria,* etc., it may be said in general that such plants bloom in spring, then die down, the fleshy underground parts remaining dormant for from seven to ten months, or until spring comes again. Since this phenomenon occurs annually, under the conditions that prevail each year, it might appear at first sight that it was "autonomic" in character, but the experiments of Klebs before referred to with *Ficaria, Glechoma, Ajuga,* etc., indicate that such plants may not only be forced into growth by careful handling during their resting stage, but they may be *kept growing continuously all the year.* This proof then, results in the conclusion that for this class of plants the rest is in some way due to outward conditions (their requirements being different from those of woody plants), and thus similar to the winter rest and to the other forms of enforced summer rest.

We can now look at plants as organisms disposed to have an almost unbroken growth and only hindered from doing so by external conditions. The so-called "Malta" potatoes are said to have no resting period, that is, will grow at any time during the year when conditions are favorable. Schmid [19] planted, on October 21, as early and as late varieties of potatoes as he could procure. Both kinds grew and formed new tubers, and, on November 8, the new crops were harvested and immediately planted. These in turn grew and the new ones were again planted April 6 and these also grew. He had the same results with onions in autumn and winter, except he reports the latter grew even more readily than the potatoes.

[19] Schmid, B., Ueber die Ruheperiode der Kartoffelknollen. Bericht. d. Deutch. Bot. Gesellsch. Bd. XIX. Heft 2.

Klebs[20] also reports the same results with the sort of potato known as "Maercker." In both these instances no further treatments were given beyond supplying warmth and a good circulation of air. On March 13, 1906, the writer of this report planted in pots in the greenhouse ordinary potatoes secured from the German market in the city of Halle. They grew and on May 10 young tubers from 1 to 2 cm. in diameter were harvested, cut into pieces and planted. These began to grow on May 27, thus showing that they apparently had no resting period.

In this connection it may be of interest to remark that in the Southern States it is a practice among some of the gardeners to secure their seed potatoes from the North. These grow and mature quickly and are used for seed for a second planting, which is done immediately after harvesting. In this way two crops are annually produced, but it is necessary to procure new Northern seed each year.

The degree of intensity of the rest we have seen varies greatly among the different species, but this is not surprising when we notice the great differences in the other characters. Without an experimental test one cannot know the extent of the dormancy of any particular plant in winter. It may be aroused into growth easily or the rest may be so profound that it can be awakened with great difficulty or not at all, immediately. However, under the most extreme cases of rest one should be cautious in saying that a plant is completely dormant. Even when in a state of winter rest a plant is not necessarily inactive in all respects, for, according to Müller-Thurgau,[21] Simon,[22] and others, respiration continues to go on. In this regard it is interesting to note that Simon, after investigating the subject of the retention of some of the growth activities during the winter rest, gives this conclusion: ". . . . that so far as some of the functions of growth and metabolism and also the respiration are concerned, woody plants have no rest period, for, even in winter, under favorable conditions, these activities reach a relatively high intensity."

In discussing the rest period Johannsen[23] states that it is in the nature of a "hindrance" (Hemmung) which prevents growth, but when growth is secured by treatment, it is because the "hindrance"

[20] Klebs, Georg, Willkürliche Entwickelungsänderungen bei Pflanzen. p. 137.

[21] Müller-Thurgau, H., Landwirtschaftlichen Jahresbericht. Bd. 14 p. 861.

[22] Simon, S., Untersuchungen ueber das Verhalten einiger Wachstumsfunktionen, sowie der Atmungstätigkeit der Laubhölzer während der Ruheperiode. Jahresbericht für wissenschaftliche Botanik. Bd. 43. Heft 1.

[23] Johannsen, W., Das Aetherverfahren beim Frühtreiben mit besonderer Berücksichtigung der Fliedertreiberei. 1906. p. 47.

is reduced or weakened, or, that the power of growth (Wachstumstätigkeit) is increased. Little is known of the exact nature of the winter rest period but since it appears to be a habit induced by oft-repeated influences, the cause must be sought in the life centers where impressions of any other kind are recorded.

EFFECTS OF ETHER, FREEZING, DRYING, ETC.

The whole question of how vapors and gases, freezing and desiccation, cause growth to begin in dormant plants, or serve as stimulants in plants that are already in growing condition, is as little understood as the rest period itself. According to Drude,[24] Leclerc, more than fifty years ago, was the first to investigate the effects of ether on plants. Since then, however, during the last twenty or twenty-five years, many investigators have tested the effects of ether, as well as other vapors and gases, on plants in connection with the experimental study of respiration, transpiration and movement, but it is only recently—the last five or six years—that they have been used for forcing dormant plants into growth. As early as 1873 and 1874 Heckel[25] studied the behavior of *Berberis* stamens, while they were under the influence of chloroform. Again in 1874[26] he used chloroform, chlorohydrate and nitrous oxide on the stamens of both *Berberis* and *Ruta,* and also during the same year[27] both anesthetics and narcotics were used on many species of plants in the study of sensitiveness and movement. In 1879 Giglioli[28] used ether, etc., in

[24] Drude, O., Naumann, A., und Ledien, F., Ueber die von Ostern 1902 bis 1903 im Botanischen Garten zu Dresden angestellten, den Gartenbau betreffenden Versuche, etc. Jahresber. VII. der "Flora" zu Dresden.

[25] Heckel, E., Des l'irritabilité des étamines, distinction dans ces organes de deux ordres de mouvements. Bull. de la Soc. Botanique de France. t. 20. pp. 280-281.

[26] Heckel, E., Différentiation des mouvements provoqués et spontánés. Etude sur l'action de quelques agents réputés anesthésiques sur l'irritabilité fonctionelles des étamines de *Mahonia.* Comptes rendus LXXVIII, No. 12, pp. 856-859, et Bull. d. l. Soc. Botanique de France. t. 21, pp. 101-103.

[27] Heckel, E., De l'irritabilité fonctionnelle dans les étamines de *Berberis.* Comptes rendus. t. LXXVIII, No. 14, pp. 985-988, et Bull. de la Soc. Botanique de France, t. 21, pp. 95-98.

———, Mouvement provoqué dans les étamines de *Mahonia* et de *Berberis*; conditions anatomiques de ce mouvement. Comptes rendus, t. LXXVIII, No. 16, p. 1162-1164, et Bull. d. l. Soc. Botanique de France, t. 21, pp. 208-210.

———, Du mouvement provoqué dans les étamines des *Syantherées.* Comptes rendus, t. LXXIX, No. 16, pp. 922-925, et Bull. d. l. Soc. Botanique de France, t. 21, pp. 308-311.

———, Du mouvement dans les étamines du *Sparrmannia africana* L. fils, des *Cistes* et des *Heliamthum.* Comptes rendus, t. LXXIX, No. 1, pp. 49-52.

[28] Giglioli, J., Resistenza dei semi, e specialmente dei semi di agenti chimici gassosi e liquidi. Gazetta Chimica Italiana, IX.

both gaseous and liquid form on dry and wet seeds to test the effects on their germinating powers, and found that all seeds have not the same powers of resistance to the treatment, but that the wet ones were killed much easier than the dry ones. It was not stated whether growth was hastened or not. Ten years later Townsend[29] tested the effects of ether on the germination of seeds and spores. He found that slight ether fumes caused the following to germinate quicker than under normal conditions: Seeds of *Zea Mais, Avena sativa, Phaseolus vulgaris,* and *Cucurbita pepo;* spores of *Mucor* and *Penicillium.* The subject of forcing seeds into growth by the use of gases and vapors and like treatments, however, yet remains uninvestigated except for incomplete, isolated cases. In 1905 Latham[30] found that ether and chloroform hastened the development of spores of *Sterigmatocystis nigra* and *Penicillium glaucum.*

The earlier investigators were much puzzled over the effects of ether on growing plants. In 1879 Arloing[31] caused a *Mimosa* plant to absorb ether and chloroform mixed with water, through a tube. The resulting "intoxication" lasted nearly two hours, during which time all sensitiveness was lost, but returned again with the passing of the effect of the drugs. Macchiati[32] used the same drugs for the same purpose in 1880 and gave it as his opinion that the vaporizing of the materials caused a lowering of the temperature about the plant to such an extent as to prevent movement, but this was disproven by Cugini[33] the next year. Two years later, 1883, Macchiati[34] decided that the anesthetics had the same effect on plants as on animals, that is, that they are absorbed. In 1882 Detmer[35] used chloroform in studying respiration in young pea plants. The treated plants made no advance and finally died off, it being explained that chloroform fully restrained the growth of the cells but that respiration continued vigorously. Tassi[36] in 1884 dipped freshly cut flowers

[29] Townsend, C. O., The effect of ether upon the germination of seeds and spores. Botanical Gazette, XXVII. pp. 456-458.

[30] Latham, Marion Elizabeth, Stimulation of *Sterigmatocystis* by chloroform. Bull. Torrey Bot. Club, 32. pp. 337-351.

[31] Arloing, M., Sur un nouveau mode d'administration de l'éther, du chloroforme et du chloral à la sensitive; application à la détermination de la vitesse des liquides dans les organes de cette plante. Comptes rendus, t. 89. p. 442.

[32] Macchiati, L., Del Movimento periodico spontaneo degli stomi nelli *Ruta bracteosa* DC. e nello *Smyrnium rotundifolium* DC. Nuovo Giorn. Bot. Ital. XII. 3. pp. 243-247.

[33] Cugini, G., Intorno all'azione dell'etere e del cloriformio sugli organi irritabili delle pianti. Nuovo Giorn. Bot. Ital. XIII. 4. pp. 288-291.

[34] Macchiati, L., Ancora sugli anestetici delle piante. Nuovo Giorn. Bot. Ital. XV. 1. pp. 214-221.

[35] Detmer, W., Ueber die Einwirkung verschiedener Gase, insbesondere des Stickstoffoxydulgases auf Pflanzenzellen. Landw. Jahrb. XI, pp. 227, 228.

[36] Tassi, F., Degli effetti anestetici nei fiorie. Nota. Siena.

of *Croccus, Oxalis,* etc., in solutions of anesthetics and narcotics and noted the results on the opening and closing of the floral parts. The experiments were repeated the following year.[37]

Laurén[38] in 1891 investigated the effects of ether vapor on very young seedlings. Transpiration, as affected by anesthetics, was studied in 1892 by Schneider,[39] and in 1896 by Dixon;[40] also in 1896 Johannsen[41] reported results of work on transpiration and study of the rest period. Sandsten[42] experimented with a number of gases and vapors in regard to their influences on plant growth in 1898. He found that ether dissolved in water accelerated the germination of seeds, and that the fumes of ammonia, chloroform and ether, caused an increased growth in twigs and young plants.

The above review is not intended to be complete, but is only given to show some of the steps in the development of studies on the effects of ether on plant life. In the bibliography list at the end of this bulletin will be found a practically complete list of references to the literature bearing upon the subject of this paper.

Although much work had been done with anesthetics and narcotics on growing vegetables, it was with the appearance of Johannsen's "Aetherverfahren beim frühtreiben mit besonderer Berücksichtigung der Fliedertreiberi," in 1900, that there was aroused a wide-spread interest in the use of ether and chloroform for forcing plants into growth, and since that time there have been a great many references in botanical and gardening periodicals to their practical use.

Regarding the workings of the ether and chloroform Johannsen[43] speculates at length. He does not say that the ether exerts a specific effect on the protoplasm, but from his discussion it is inferred that he believes this to be the case. He declares that the workings of ether and chloroform could be in only two ways, that they act on the "power of growth" (Wachstumstätigkeit), or on the "hindrance" (Hemmung), or possibly on both. This author expressed his disbelief, however, in the theory that the effects of ether,

[37] Tassi, F., Degli effetti anestetici del cloridrato di cocaina sui fiori di alcune piante. Bollettino della Soc. tr. Cult. d. sci. med. d. Siena.

[38] Laurén, W., Om inverkan af eterångor på groddplantors andning.

[39] Schneider, A., Researches on the influence of anesthetics on transpiration. Minn. Acad. Science 17. p. 232.

[40] Dixon, Henry H., On the effects of stimulation and anesthetic gases on transpiration. Preliminary notes. Proc. Royal Irish Acad. III. ser. vol. 4, pp. 618-626.

[41] Johannsen, W., Aether- und Chloroform-Narcose und deren Nachwirkung. Bot. Centralblatt. Bd. 68. pp. 337-338.

[42] Sandsten, E. P., The influences of gases and vapors upon the growth of plants. Minn. Bot. Stud. 2. ser. I. pp. 53-68.

[43] Johannsen, W., Das Aetherverfahren beim Frühtreiben mit besonderer Berücksichtigung der Fliedertreiberei. 1906. pp. 24-60.

freezing and drying were the same, even though their results are similar. Regarding drying in particular he says, "as a result of my experience it is clear that the effects of desiccation and treating with ether and chloroform are not similar. Only one example will be cited: The seed of the two-row or bearded barley (*Hordeum zeocrithon*) have a pronounced rest period. Drying has no effect at all, while a very slight amount of ether causes them to start into growth in the shortest possible time."[44] He also disagrees with Dubois[45] who reported that ether exerts a strong dehydrating effect and is therefore similar to freezing and drying.

In the writer's experiments it was often noticed that there was considerable moisture in the glass jars after etherizing a big bundle of twigs for forty-eight hours or longer. Whether this moisture resulted from the ordinary transpiration, which was thought to be the case, or had been extracted by the ether, is not clear. The quantity of water in the jar was especially noticeable following the etherization of twigs that had been for several days in the dark-chamber. These facts are significant when taken in connection with the experiments of Jumelle,[46] who found in 1890 that ether caused an increase of transpiration in the light and a decrease in darkness. There was no ether in the dark-chamber in the writer's experiments, but the air there was saturated with moisture, and hence transpiration was reduced to a minimum, so that conditions were favorable, when they were removed and placed in the jar, for the ether to cause the plants to transpire to their utmost, in accordance with Jumelle's findings.

It has also been found that ether increases the respiration, but this in itself does not constitute growth. Müller-Thurgau[47] has shown that growth is preceded by sugar being made available as fuel for the greatly increased respiration and that this sugar comes from a reserve supply as such, or is formed from starch or other carbohydrates present, through the agency of diastase of ferment. He further found that sugar is formed very rapidly in potatoes at 0 degrees C. At this temperature, it is explained, the protoplasmic activities are much depressed and hence the fermentation processes produce more sugar than is used, and it accumulates. But at higher temperatures respiration and the formation of starch rapidly increase

[44] Johannsen, W., Das Aetherverfahren beim Frühtreiben mit besonderer Berücksichtigung der Fliedertreiberei. 1906, p. 57.

[45] Dubois, R., Mécanisme de l'action des anésthésiques. Rev. gen. d. Sci. pures et appliqués, 2. an. No. 17. pp. 261-567.

[46] Jumelle, H., Influence des anesthésiques sur la transpiration des végétaux. Rev. gen. de Bot. 2. pp. 417-432.

[47] Müller-Thurgau, H., Ueber Zuckeranhäufung in Pflanzenteilen infolge niederer Temperatur. Landw. Jahresber. 11. pp. 751-828.

and at 10 degrees the protoplasm needs nearly all of the sugar that has been formed and at 20 degrees all the newly formed sugar—as well as any reserve supply that might have been there—is consumed, and more would be if it were available. After holding potatoes at 0 degrees for a long time and then removing them to a warm room, it was found that the respiration during the first week was much greater than normal, which he believed to be the indirect result of the large amount of sugar that was placed at the disposal of the protoplasm, and not through any direct stimulus the protoplasm had received from the freezing.

The foundation principle to be worked from is whether a given agency, as ether, drying, etc., will cause the formation of sugar in a plant, and as to whether this has been done can only be decided by quantitative chemical determinations. But will ether cause any such results? It is of interest here that Latham[48] found that in chloroformed fungi the increased growth was accompanied by less acid formation and less sugar consumption, thus indicating increased economy in metabolism. Gerrassimow[49] studied the effects of ether on *Spirogyra* and concluded that the increased growth was caused by the anesthetic having stimulated the cell nucleus.

Just here it will be appropriate to notice the results of the experiments with the young oaks growing in pots, previously mentioned (see pages 12 and 80). In this case there were two agencies that acted on the same plant, both producing an increased growth. These agencies were freezing and ether, but it was undoubtedly the former that caused growth to begin, although the extent of the freezing was very slight. Since freezing and ether affect plants similarly, it seems reasonable to conclude that the latter does not exert any specific chemical action on the protoplasm, which may somewhat narrow the question, but by no means answers it.

It is popularly supposed that drying is very similar to freezing, as both remove water from the plant body and the latter at least, quickly condenses the cell sap. They may, however, not be identical in their effects. Freezing, according to Molisch,[50] Mez,[51] and Pfeffer,[52] forces the moisture out of the cells in the form of chemically pure water, leaving all of the salts behind. But these processes

[48] Latham, Marion Elizabeth, Stimulation of *Sterigmatocystis* by chloroform. Bull. Torrey. Bot. Club, 32. pp. 337-351.

[49] Gerrassimow, J., Aether-Kulturen von *Spirogyra*. Flora. Bd. XCIV. pp. 79-88.

[50] Molisch, Hans, Untersuchung ueber das Erfrieren der Pflanzen. pp. 16-26.

[51] Mez, Carl, Neue Untersuchungen ueber das Erfrieren eisbeständiger Pflanzen. Flora oder Allg. bot. Zeitung. Bd. 94. Heft 1. p. 94.

[52] Pfeffer, W., Pflanzenphysiologie. Bd. II. 1904. p. 308.

need not necessarily injure the cells, merely condensing the cell sap, while the process of drying leaves different effects. Schröder [53] found that severely dried cells were broken and that the protoplasmic bodies were thickened ("trübe"), opaque, and appeared denser and darker than in turgescent cells. He also noted the presence of air in the cells.

Aymard [54] gave it as his opinion that anesthetics produce the same effects on vegetation as freezing or drought; that they act on vegetable tissue as dehydrating agents. As proof of this, he found that roots of the lily-of-the-valley placed under a bell-jar with phosphoric anhydrid and other drying liquids, forced even more quickly than when submitted to ether vapor. It was also found that etherized plants lose considerable in weight.

A dark-chamber, which is also very moist, may exert an effect in causing growth, in two ways. The beneficial effects of a uniform temperature of 20 degrees or 22 degrees, combined with a high humidity, are too well known to need comment. At the high temperature of 22 degrees C. respiration would be very vigorous and sugar rapidly consumed, but under the favoring influence of the darkness [55] and warmth, the ferments would be very active and sugar could be formed in greater quantities than normally. This may account for the large percentage of the twigs that grew in the dark-chamber, but there is no explanation for the slowness with which this growth took place, a feature which is so prominent in the experimental data.

In conclusion it may be added that whether etherizing, drying and freezing are alike or related in the nature of their workings or not, the experimental results herein recorded show that all will break the winter resting period of plants. Etherizing has been referred to as "stimulating" or "poisoning" the plants, the freezing and drying as concentrating the cell sap and therefore also as "stimulants," but all of these terms bring us no nearer to an answer to the question. It is very probable, however, that none of the agents used for forcing growth exert any specific action, but are rather the means, possibly in distinctly different ways, of setting into activity, indirectly, certain complicated vital machinery which results in growth.

[53] Schröder, G., Ueber die Austrocknungsfähigkeit der Pflanzen. Tübinger untersuchungen. Bd. II.

[54] Aymard fils, J., Les anesthésiques et le forcage des plantes.

[55] Green, J. R., Influence of light on diastase. An. of Bot. Vol. VIII. pp. 561-567.

LITERATURE.

The literature mostly used during the course of the investigation was as follows: Johannsen's well-known "Aetherverfahren beim Frühtreiben, etc.," editions of 1901 and 1906, which served as a basis for some of the mechanical operations, for example, the quantity of ether to use and the length of time for it to act, as well as for a number of other useful suggestions. In the discussion, Klebs' valuable books "Willkürliche Entwickelungsänderungen bei Pflanzen," Chap. VI, and "Ueber Variationen der Blüten," Abschnitt IV, as well as Pfeffer's "Pflanzenphysiologie," Zweiter Band, 1904, were used. Occasional references throughout this report indicate other sources consulted, but there are a few authors mentioned in the list of literature at the end of this paper that are not specifically cited in the text, although they were drawn upon in the general study.

OUTLINE OF EXPERIMENTS.

The preliminary steps in the experimental study of the rest period in plants, was to find what species would grow by merely being brought into a warm, moist room, and those not so growing to be treated by different methods until growth was secured. The following outline was followed as nearly as possible:

1. *Effects of Warmth Alone.*

All of the species were placed in the greenhouse in late fall to see which would grow without treatment. For purposes of comparison the same list was again taken into the warm room in midwinter. Those that made no growth were again collected in late winter; and a few that still refused to grow were brought in just before the beginning of spring. See Tables I and II—283 species.

2. *Treatment with Ether Only.*

A number of the species that would not grow in the greenhouse and some that did, were treated with ether only. See Table III—58 species.

3. *Freezing, Etherizing and Use of Dark-Chamber.*

A list of kinds that grew with difficulty or not at all, without treatment, were treated by a few methods to force growth; viz., freezing; freezing and then etherizing; and, enclosing for a time in a moist, dark-chamber. See Table VI—35 species.

4.—*Etherizing, Drying, Freezing, and Dark-Chamber, Singly and in Combination.*

A longer list of sorts that, for the most part, were known to be difficult to force into growth, were treated as follows: with ether,

by drying, by freezing, enclosing in moist dark-chamber, and with combinations of freezing, etherizing and the use of the dark-chamber. See Table IX—70 species.

5. *Miscellaneous and Special Tests.*

These tests for the most part employed ether and drying, but also in addition the use of chloroform both as a liquid and as a gas; ether as a liquid, desiccation with alcohol, with salt solution, and with sulphuric acid; injecting with sugar and water solutions under pressure; moist light-chamber; and by wounding the buds. Treatment of a few oaks growing in pots; also test of a short list of species of Mediterranean plants in the greenhouse without treatment.

GENERAL NOTES ON METHODS AND CONDITIONS OF THE EXPERIMENTS.

It was not possible to secure potted plants, so small branches from 30 to 60 centimeters long were used, each being securely labeled and kept standing in water when in the greenhouse or dark-chamber. After each treatment plants were immediately transferred to the greenhouse, where they remained until they either grew or died. The day temperature of the greenhouse throughout the winter varied between 20° and 22° and at night from 15° to 17° C. The relative humidity ranged between 50 and 80 %.

Etherizing.

The quantity of ether used for each application was 40 grams per 100 litres of space in the vessel, regardless of the number of plants being treated at one time. The twigs were placed in cylindrical glass jars about one meter high and 20 centimeters in diameter. The tops were closed with ground glass plates having a small opening in the center to admit the ether. The plates were smeared with a soft wax and then pressed firmly down upon the rim of the jars. The ether was poured through a small funnel, which was quickly removed and the hole securely closed with a cork stopper. The covers were then held down by placing upon them jars of sand weighing 8 to 10 kilos. This precaution was necessary, as there was considerable pressure from the ether vapor. The temperature was usually between 18 and 20 C.

Freezing.

The plants were frozen in a specially prepared refrigerator. This was a wooden box about one meter high and containing approximately two hectoliters of space. The walls were thick and lined with zinc. Then there was a smaller, square-cornered vessel made of zinc which fitted inside of the refrigerator in such manner as to leave a space five or six cm. wide between the walls of the two boxes, all

around. A mixture of common salt and crushed ice was packed in the bottom of the outer box to a depth of about 10 cm., then the zinc vessel was fitted into place and the space between the walls packed with the freezing mixture. Every day the water from the melting ice was drawn off and the supply of the freezing material replenished.

The refrigerator was kept all the time in a cool basement room. The plants were placed in the inner, metal box, and a thermometer thrust in among them. Daily readings showed that the temperature varied between -5 and -10 C., depending upon the changes of the atmospheric temperature outside. For the most part the plants were exposed to a temperature of -6 to -10. After a day or two the twigs became quite brittle from the cold. Potatoes and onions placed in the box were frozen perfectly rigid in a few hours. The twigs were thawed out gradually before being removed to the warm room for further treatments.

Dark-Chamber.

The dark-chamber used was made of glass with thoroughly darkened walls, and was about one cubic meter in size. Doors at one side admitted the plants. It rested on top of a laboratory case and in this position at the top of the room the temperature was not only somewhat higher but was more uniform than below. The temperature at a midpoint in this laboratory room varied between 18° and 20°, while in the chamber it remained almost constantly around 22°. In the chamber the twigs stood in a large vessel of water and thus the atmosphere was kept moist. The hygrometer showed the humidity to be from 90 to 92%.

Desiccation.

Except in a few special cases the twigs were air-dried in a warm, dry, laboratory room. The temperature of the room varied from 18 to 20°, and the humidity from 30 to 35%. The twigs were first carefully weighed to the tenth of a gram and then spread out on a table. At a given time each day a portion was removed, again accurately weighed, and one or two centimeters clipped from the lower ends, as the freshly cut parts soon shriveled from drying. Those dried two days or more and appearing very dry, were submerged in water for about an hour before being placed with the others in the greenhouse.

The Dates.

To make the tables as simple as possible, only two dates are given after each species. These dates are, first, the number of days that elapse from the time of treatment until the first growth was noticed, and, second, the number of days from the time of treatment

until the first buds (leaves or flowers) were fully open. In all cases these dates were reckoned from the time the plants were placed under growing conditions. In most instances the starting point was when placed in the greenhouse. An exception, however, was when the plants were treated in the dark-chamber. Here they had both warmth and moisture, and hence dates were computed from the time they were placed inside.

Controls.

For each lot of twigs treated there was at least one specimen from every species left untreated to check the results. In the greenhouse, controls and all were kept under exactly similar conditions.

EXPERIMENTAL DATA, 1905-6.

1. *A Test of Effects of Warmth Alone* (Tables I and II).

From October 28 to November 4, 1905, a set of twigs was collected representing 234 species. These were placed in the greenhouse untreated, as this was a preliminary test to find which would grow merely under the influence of warmth.

About ten weeks later—January 8 to 10, 1906, another set was collected including the 234 kinds of the first collection and 49 additional species, making a total of 283. These were placed in the greenhouse without treatment as before, to compare effects of season on the growth. In Table I are the names of all of the species of the two collections mentioned above, with the native country of each, the number of days required for growth to begin and for the buds to open fully. The figures refer to number of days from time plants were placed in the greenhouse. The characters "." and "*" indicate respectively whether the growth was from a leaf bud or from a flower bud.

TABLE I.

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905. Growth began in	Collected Oct. 20-Nov. 4, 1905. Buds fully open in	Collected Jan. 8-10, 1906. Growth began in	Collected Jan. 8-10, 1906. Buds fully open in
		Days	Days	Days	Days
Acanthopanax pentaphyllum Marsh	China & Japan	. 28	. 34	. 8	. 7
Acer campestre L.	Europe & Orient	0	0	. 17	. 25
Acer campestre L., var. hepbecarpum	Hort. form	. 41	0	. 18	0
Acer campestre L., var pulverulentum	Hort. form	0	0	. 26	0
Acer dasycarpum Ehr.	N. Amer.	0	0	. 39	. 45
Acer Ginnala Maxim	N. China & Japan	. 18	. 19	. 2	. 9
Acer macrophyllum Pursh	N. Amer.	0	0	* 31	0
Acer monspessulanum L.	S. Europe	0	0	. 12	* 20
Acer negundo L.	N. Amer.	0	0	. 25	. 34
Acer negundo L., var. californicum	California	0	0	. 38	. 45
Acer negundo L., var. crispum	N. Amer.	....	....	0	0
Acer negundo L., var. fol., arg. marg.	Hort. form	....	....	. 31	. 41
Acer negundo L., var. fol. aur. marg.	Hort. form	....	....	. 39	. 45
Acer negundo L., var. versicolor	N. Amer.	. 63	. 69	. 20	. 25
Acer negundo L., var. violaceum	N. Amer.	. 64	. 73	. 24	. 35
Acer platanoides L.	Europe	0	0	. 13	* 20
Acer Pseudo-Platanus L.	Europe	0	0	0	0
Acer spicatum L.	N. Amer.	0	0	0	0
Acer tataricum L.	E. & S. E. Europe	0	0	. 8	* 10
Acer tauricum	Europe & Orient	0	0	. 10	. 21
Aesculus chinensis Bunge	China	0	0	. 33	. 45
Aesculus flava Ait	N. Amer.	....	....	. 35	0
Aesculus Hippocastanum L.	Orient	0	0	. 20	. 25
Aesculus humilis Lindl.	N. Amer.	....	....	0	0
Aesculus macrostachya Mchx.	N. Amer.	....	....	. 25	. 45
Ailanthus glandulosa Dsf.	China & Japan	....	....	. 6	. 16
Alnus americana C. Koch.	N. Amer.	0	* 49	. 15	. 20
Alnus barbata C. A. Mey.	Caucasus	0	* 27	. 16	. 22
Alnus glutinosa Medic.	Europe, Asia, Afr. & Amer.	0	0	. 18	. 21
Alnus japonica S. & Z.	Japan	0	0	. 10	. 13
Alnus viridis DC.	Europe, Asia, & N. Amer.	....	....	0	0
Amelanchier canadensis Medic.	N. Amer.	0	0	. 5	. 22
Amelanchier ovalis Lindl.	N. Amer.	0	0	. 4	* 7
Amelanchier vulgaris Moench.	S. Europe	. 44	0	. 16	* 22
Amorpha canescens Nutt.	N. Amer.	. 38	. 50	0	0
Amorpha fruticosa L.	N. Amer.	0	0	0	0
Amygdalus communis L.	Orient	* 15	* 25	. 2	* 8
Amygdalus Gaertneriana Schlect.	Europe & Asia	. 13	. 16	. 2	* 9

TABLE I. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905. Growth began in	Collected Oct. 20-Nov. 4, 1905. Buds fully open in	Collected Jan. 8-10, 1906. Growth began in	Collected Jan. 8-10, 1906. Buds fully open in
		Days	Days	Days	Day[illegible]
Amygdalus nana L.	Asia Minor	....	....	. 8	*
Amygdalus persicoides C. Koch	Europe	....	....	. 2	*
Andromeda calyculata L.	Europe, Asia & N. Amer.	0	0	. 9	. 1[illegible]
Andromeda japonica Thunbg.	Japan	0	0	. 8	. 1[illegible]
Andromeda mariana L.	N. Amer.	. 9	. 17	. 5	. 1[illegible]
Andromeda paniculata L.	N. Amer.	0	0	. 8	. 1[illegible]
Andromeda speciosa Michx.	N. Amer.	. 12	. 0	* 3	.
Azalea mollis Blume	China & Japan	. 26	. 45	0	
Azalea pontica L.	Asia Minor	* 48	* 58	* 17	* [illegible]
Benzoin odoriferum Nas.	N. Amer.	0	0	0	
Berberis vulgaris L.	Europe & Asia	. 10	. 18	. 8	. 1[illegible]
Betula alba L.	Europe & Asia	. 25	* 27	* 7	* 1[illegible]
Betula nana L.	Europe, Asia & N. Amer.	....	....	. 2	
Betula nigra L.	N. Amer.	. 62	. 78	. 12	. [illegible]
Broussonetia papyrifera Vt.	China & Japan	. 82	. 57	. 6	*
Buddley intermedia H. B.	Mexico	. 2	. 5	. 4	.
Calophaca wolgarica Fisch.	S. Russia	. 9	. 17	. 6	. [illegible]
Calycanthus floridus L.	N. & S. Caro.	....	....	. 21	
Calycanthus occidentalis Hoot. & Arn.	California	. 9	. 16	. 6	.
Caragana arborescens Lam.	Siberia	0	0	. 3	.
Caragana arborescens Lam. var. pendula	Hort. form	. 9	. 15	. 2	.
Caragana spinosa DC.	Siberia	6	. 18	. 2	.
Carpinus americana Michx.	N. Amer.	0	0	. 34	.
Carpinus betulus L.	Europe	. 8	0	. 14	. [illegible]
Carya aquatica Nutt.	N. Amer.	0	0	0	
Carya porcina Nutt.	N. Amer.	0	0	0	
Castanea pumila Michx.	N. Amer.	0	0	. 17	
Castanea vesca Grtn.	S. Europe	0	0	0	
Catalpa Kaempferi S. & Z.	Japan	. 16	. 22	. 11	.
Catalpa syringifolia Sims.	N. Amer.	. 17	. 24	. 5	.
Cedrela sinensis Juss.	China	0	0	. 9	. [illegible]
Celastrus scandens L.	N. Amer.	0	0	. 17	.
Celtis occidentalis L.	N. Amer.	. 83	. 87	* 1	
Celtis Tournefortii Lam.	Orient	0	0	. 10	.
Cercidiphyllum japonicum S. & Z.	Japan	0	0	. 21	.
Cercis canadensis L.	N. Amer.	0	0	. 10	
Cercis Siliquastrum L.	Europe & Orient	0	0	. 21	
Chionanthus fragrans Lindl.	N. Amer.	0	0	. 9	

TABLE I. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905. Growth began in	Collected Oct. 20-Nov. 4, 1905. Buds fully open in	Collected Jan. 8-10, 1906. Growth began in	Collected Jan. 8-10, 1906. Buds fully open in
		Days	Days	Days	Days
Clethra acuminata Michx.	N. Amer.	0	0	0	0
Clethra alnifolia L.	N. Amer.	0	0	9	. 13
Clethra barbinervis S. & Z.	Japan	0	0	. 6	. 9
Colutea arborescens L.	Europe & Orient	0	0	. 10	0
Colutea cruenta Ait.	S. Europe & Orient	. 8	. 24	. 4	. 7
Comptonia asplenifolia Banks	N. Amer.	. 25	. 28	. 6	. 9
Cornus alba L.	Siberia	0	0	. 7	. 10
Cornus candidissima Mill.	N. Amer.	0	0	. 10	. 14
Cornus Mas L.	Middle & S. Europe	. 18	. 21	* 3	* 5
Cornus sanguinea L.	Europe & Orient	0	0	. 11	. 13
Corylus Avellana L.	Europe & Asia	0	0	* 4	. 22
Corylus Colurna L.	Asia Minor & Turkey	0	* 25	* 6	. 21
Cotoneaster vulgaris Ldl.	Europe & Orient	0	0	. 4	. 10
Crataegus betulaefolia	Hort. form	. 7	. 25	. 3	. 9
Crataegus chinensis Steud.	China	. 11	. 22	. 3	. 9
Crataegus coccinea L.	N. Amer.	0	0	. 8	. 21
Crateagus flava Ait.	N. Amer.	0	0	. 6	. 10
Crataegus floribunda C. Koch	N. Amer.	0	0	. 16	. 26
Crataegus latifolia L.	N. Amer.	0	0	. 16	0
Crataegus macracantha Lodd.	N. Amer.	0	0	. 21	0
Crataegus melanocarpa M. B.	Caucasus	. 20	. 44	. 6	. 15
Crataegus nigra W. & K.	Hungary	* 6	. 18	. 3	. 8
Crataegus oliveriana B. & DC.	Europe	. 15	. 28	. 5	. 26
Crataegus Oxyacantha L.	Europe	. 15	. 36	. 3	. 7
Crataegus Oxy. L., var. fl. rubr. pl.	Hort. form	. 5	. 15	. 3	. 10
Crataegus Oxy. L., var. fol. tricolor	Hort. form	. 12	. 35	. 4	. 12
Crataegus punctata, var. aurea Jacq.	N. Amer.	0	0	. 17	. 26
Crataegus spinosissima Lodd.	Siberia	0	0	. 7	. 11
Crataegus stipulacae	Europe	0	0	. 21	. 36
Crataegus tanacetifolia Per.	Asia Minor	0	0	. 18	. 39
Cydonia japonica Pers.	Japan	* 6	* 16	. 3	. 7
Cydonia vulgaris L.	S. Europe	. 6	. 15	. 7	. 11
Cytisus laburnum L.	Europe	....	....	. 9	. 0
Cytisus weldeni Vis.	S. Hungary	* 5	* 21	. 3	0
Deutzia crenata S. & Z.	Japan	. 9	. 16	. 4	. 9
Deutzia gracilis S. & Z.	Japan	. 10	. 21	. 3	* 17
Deutzia scabra Thb.	Japan	....	....	. 4	. 9
Diervilla canadensis Willd.	N. Amer.	0	0	0	0

TABLE I. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905. Growth began in	Collected Oct. 20-Nov. 4, 1905. Buds fully open in	Collected Jan. 8-10, 1906. Growth began in	Collected Jan. 8-10, 1906. Buds fully open in
		Days	Days	Days	Days
Diospyros virginiana L.	N. Amer.	....	....	0	[illegible]
Elaeagnus argentea Pursh.	N. Amer.	0	0	. 7	[illegible]
Erica carnea L.	S. Europe	0	0	. 20	[illegible]
Euomymus alatus Rupr.	China & Japan	0	0	. 5	. 2[illegible]
Euonymus americanus L.	N. Amer.	....	....	. 20	[illegible]
Euonymus europaeus L.	Europe & Orient	0	0	. 8	. 1[illegible]
Fagus sylvatica L.	Europe & W. Asia	0	0	. 38	[illegible]
Fagus sylvatica L., var. atropurpurea	Europe	....	....	. 36	. [illegible]
Forsythia suspensa Vahl.	China & Japan	* 7	* 14	* 8	* [illegible]
Fraxinus americana L.	N. Amer.	....	....	0	[illegible]
Fraxinus excelsior L.	Europe & W. Asia	....	....	0	[illegible]
Fraxinus excelsior, var. hetrophylla, L.	Asia	....	....	. 33	. 3[illegible]
Fraxinus oregona Nutt.	N. Amer.	....	....	0	[illegible]
Fraxinus Ornus L.	S. Europe	0	0	0	[illegible]
Ginkgo biloba L.	Japan	0	0	. 19	. 2[illegible]
Gleditschia triacanthos L.	N. Amer.	0	0	. 5	. 1[illegible]
Gymnocladus canadensis Lam.	N. Amer.	....	....	. 5	. 1[illegible]
Halesia tetraptera L.	N. Amer.	0	0	. 10	. 3[illegible]
Halimodendron argenteum Fisch.	Siberia & Tartary	. 9	. 14	. 7	. 1[illegible]
Hamamelis virginiana L.	N. Amer.	0	0	0	
Hippophae rhamnoides L.	Middle Europe & N. Asia.	. 6	. 11	. 4	. 1[illegible]
Hydrangea radiata Walt.	N. Amer.	....	....	0	
Itea virginica L.	N. Amer.	0	0	. 7	. 1[illegible]
Jasminium fruticans L.	S. Europe, N. Afr. & Orient	....	....	. 10	
Juglans cinerea L.	N. Amer.	....	....	. 22	. 1[illegible]
Juglans nigra L.	N. Amer.	. 60	. 65	. 22	. 1[illegible]
Juglans regia L.	Europe & Asia	0	0	0	
Kalmia angustifolia L.	N. Amer.	0	0	0	
Koelreuteria paniculata Laxm.	China	0	0	. 9	
Ledum latifolium Jacq.	N. Amer.	0	0	0	
Ledum palustre L.	Europe, Asia & N. Amer.	....	....	. 9	* [illegible]
Ligustrum vulgare L.	Europe	. 7	. 19	. 3	. [illegible]
Liquidambar styraciflua I.	N. Amer.	0	0	. 38	. [illegible]
Liriodendron tulipifera L.	N. Amer.	0	0	0	
Lonicera alpigena L.	Europe	. 4	. 17	. 13	. [illegible]
Lonicera Ledebourii Esch.	California	. 10	. 63	. 5	. [illegible]
Lonicera nigra L.	Europe & Asia	. 5	. 26	. 6	. [illegible]
Lonicera tatarica L.	Siberia	. 7	. 14	. 3	. [illegible]

TABLE I. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

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SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905. Growth began in	Collected Oct. 20-Nov. 4, 1905. Buds fully open in	Collected Jan. 8-10, 1906. Growth began in	Collected Jan. 8-10, 1906. Buds fully open in
		Days	Days	Days	Days
Lonicera villosa DC.	S. Hungary	0	0	. 4	. 8
Lycium barbarum L.	Europe & Orient	. 8	. 12	. 2	. 8
Maclura tinctora Don. & Steud.	N. Amer.	0	0	. 6	. 11
Magnolia acuminati L.	N. Amer.	. 29	. 48	* 25	. 36
Magnolia Soulangeana Hort.	Japan	* 11	* 25	* 9	0
Mespilus germanica L.	Europe	. 14	. 64	. 10	. 17
Morus alba L.	Asia Minor & W. Asia	0	0	. 7	. 14
Myrica cerifera L.	N. Amer.	. 26	. 38	. 5	. 18
Myrica Gale L.	Europe & N. Amer.	0	0	. 6	* 9
Nuttalia cerasiformis T. & Gr.	N. Amer.	0	0	. 1	. 6
Ostrya vulgaris Willd.	S. Europe & Orient	0	0	. 32	. 0
Philadelphus Gordonianus Lindl.	California	0	0	. 11	. 21
Photinia villosa DC.	Japan	....	....	. 12	. 19
Platanus orientalis L.	Europe & Orient	. 23	. 31	. 7	. 20
Populus balsamifera Lyall	California	....	....	. 18	. 19
Populus canadensis Foug.	N. Amer.	. 61	. 68	. 20	. 24
Populus candicans Ait.	Asia & N. Amer.	. 32	. 36	. 16	. 19
Populus monilifera Rosier	N. Amer.	. 68	. 68	. 19	. 25
Populus pyramidalis Ait.	S. Europe	. 31	. 37	. 8	. 13
Prunus acida Dum.	Europe	* 17	. 28	. 6	. 19
Prunus Armeniaca L.	Caucasus	....	....	. 4	. 14
Prunus avium L.	Europe & Orient	. 5	. 22	. 4	* 6
Prunus cerasus L.	Asia Minor	* 13	* 21	. 6	. 19
Prunus domestica L.	Caucasus	. 28	. 32	. 6	* 15
Prunus mahaleb L.	S. Europe & Orient	. 60	0	. 12	. 18
Prunus padus L.	Europe & Asia	0	0	. 7	. 12
Prunus Persica Stokes	Asia	0	0	* 6	0
Prunus Pissardi Carr.	Orient	....	....	. 3	. 13
Prunus serotina Ehr.	N. Amer.	0	0	* 5	. 14
Prunus triloba Lindl.	China	* 12	* 25	* 4	* 8
Prunus virginiana L.	N. Amer.	* 51	0	. 7	. 20
Ptelea trifoliata L.	N. Amer.	0	0	0	0
Pterocarya caucasica C. A. Mey	Orient	....	....	. 5	. 8
Pyrus americana DC.	N. Amer.	0	0	. 17	. 20
Pyrus Aria Ehrh.	Europe & Asia	....	....	. 22	. 27
Pyrus Aria, var. edulis Ehr.	Europe & Asia	0	0	0	0
Pyrus aucuparia Ehrh	Europe & Asia	. 40	. 52	. 5	. 10
Pyrus cerasifera Tausch.	Siberia	. 8	. 13	. 4	. 9

TABLE I. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905.		Collected Jan. 8-10, 1906.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days
Pyrus communis L.	Europe & Asia	. 15	. 26	* 8	. 9
Pyrus graeca Hort.	Europe & Asia	0	0	. 12	0
Pyrus malus L.	Europe & Asia	. 22	. 29	. 5	. 13
Pyrus microcarpa DC.	N. Amer.	. 26	. 32	. 7	. 13
Pyrus nivalis Jacq.	Europe & Asia	....	....	. 6	. 14
Pyrus Poliveria L.	Europe	....	....	. 7	. 20
Pyrus prunifolia Willd.	Siberia	. 4	. 11	. 5	. 9
Quercus alba L.	N. Amer.	0	0	0	0
Quercus ambigua W.	N. Amer.	. 28	. 39	0	0
Quercus Cerris L.	S. Europe & Asia	....	....	0	0
Quercus coccinea Wang.	N. America	0	0	0	0
Quercus Dshorochensis C. Koch.	Europe	0	0	0	0
Quercus imbricaria Michx.	N. America	0	0	. 6	0
Quercus macranthera F. & M.	Caucasus	0	0	0	0
Quercus macrocarpa Michx.	N. America	. 59	* 63	0	0
Quercus olivaeformis Michx.	N. America	0	0	0	0
Quercus pedunculata W.	Europe N. Africa & Orient.	. 30	. 40	. 19	. 29
Quercus pedunculata, var. fastigiata W.	S. Europe	....	....	. 6	. 21
Quercus pubescens W.	Europe & W. Asia	. 20	0	. 18	. 21
Quercus ramosa Booth	N. America	. 49	. 61	. 24	. 31
Quercus rubra L.	N. America	0	0	. 17	. 21
Quercus tomentosa Michx.	N. America	0	0	. 28	. 35
Rammus Pallasii Fisch. & Mey	Europe & Asia	. 20	. 23	. 10	. 15
Rhamnus frangula L.	Europe & Siberia	. 21	. 25	. 10	. 14
Rhamnus grandifolia F. & M.	Caucasus & Persia	. 11	. 29	. 12	. 19
Rhododendron ponticum var. Cunninghami L.	S. Europe & Asia Minor	0	0	0	0
Rhodora canadensis L.	N. America	* 28	* 32	. 8	. 26
Rhus Toxicodendron L.	N. America	....	....	* 17	* 30
Rhus typhina L.	N. America	....	....	. 5	. 10
Rhus vernicifera DC.	Japan	....	....	. 11	. 16
Rhus viridiflora Poir.	N. America.	....	....	. 4	. 9
Ribes aureum Pursh.	N. America	. 22	. 46	. 14	. 17
Ribes multiflor W. & K.	....	. 11	0	. 5	. 14
Ribes nigrum L.	Europe and Asia	. 16	0	. 6	. 15
Ribes rubrum L.	Europe, Asia & America	. 14	0	. 7	. 16
Ribes sanguineum Pursh.	N. America	....	....	. 4	. 18
Robinia Pseud-acacia L.	N. America	....	....	. 13	0
Robinia Pseud-acacia var. amorphaefolia L.	N. America	....	....	. 9	. 13

TABLE I. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

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SPECIES.	HABITAT.	Collected Oct. 20-Nov. 4, 1905.		Collected Jan. 8-10, 1906.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days
Robinia Pseud-acacia var. semperflorens L.	N. America	. 56	. 68	0	0
Robinia viscosa Vent.	N. America	. 18	. 25	. 11	. 15
Rosa aromatica multiflor Thunb.	Japan	. 4	. 9	. 4	. 5
Rosa canina L.	Europe & Asia	. 8	. 13	. 2	. 6
Rosa Gmelini Bunge	Siberia	. 7	. 14	. 4	. 7
Rosa rubrifolia Vill.	Europe	. 15	. 28	. 7	. 14
Rosa rugosa Thnbg.	Japan	. 8	. 11	. 5	. 7
Rubus Idaeus L.	Europe & Orient	. 9	. 23	. 9	. 15
Salisburia adiantifolia Sm.	China & Japan	0	0	. 24	0
Salix acuminata Lange.	Europe	0	0	. 6	* 10
Salix alba L.	E. Asia & N. Africa	. 9	. 24	. 9	. 12
Salix alba argentea Wimm.	Europe, Asia & N. Africa	. 8	. 22	. 10	. 13
Salix alba, var. vitellina L.	E. Asia & N. Africa	....	....	. 9	. 15
Salix alba vitellina pendula L.	E. Asia & N. Africa	. 7	. 11	. 5	. 6
Salix argentea Smith	Europe & Siberia	....	....	* 2	. 0
Salix daphnoides Vill.	Europe & Asia	. 18	. 24	* 5	* 6
Salix laurina Sm.	Europe	. 7	. 27	. 10	. 15
Salix mollissima Ehrh.	Europe	. 7	. 14	. 5	. 8
Salix pentandra L.	Europe & Asia	0	0	* 5	* 10
Salix viminalis L.	Europe & Asia	0	0	. 7	. 11
Salix vitellina L.	Europe, Asia & N. America.	. 9	. 14	. 5	. 8
Sambucus nigra L.	Europe, Orient & Ural	. 8	. 7	. 2	. 3
Sophora Japonica L.	Japan & China	0	0	0	0
Sorbus graeca Lodd. & Steud.	Europe & Asia	0	0	. 15	. 20
Spiraea Lindleyana Wall.	Asia	. 8	. 24	. 7	. 13
Spiraea sorbifolia L.	Asia	. 1	. 5	. 1	. 3
Staphylea pinnati L.	S. & E. Europe	0	0	* 11	0
Staphylea trifolia L.	N. America	....	....	. 4	. 14
Symphoricarpus racemosus Michx.	N. America	. 4	. 40	. 6	. 14
Syringa chinensis Willd.	China	. 10	. 14	. 5	. 8
Syringa emodi Wall.	Himalaya	. 37	. 44	. 14	. 22
Syringa Josikaea Jacq.	Hungary	. 22	. 33	. 12	. 20
Syringa vulgaris L.	Orient	. 9	. 56	. 4	. 7
Tamarix gallica L.	Europe, Asia, Africa	. 61	. 66	* 9	. 20
Tilia alba Ait	N. America	....	....	. 21	0
Tilia argentea DC.	Europe	. 24	. 35	. 10	0
Tilia euchlora C. Koch.	Orient	....	....	. 18	0
Tilia grandifolia Ehr.	Europe	0	0	. 18	. 21

TABLE I. (*Continued.*)

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		Days	Days	Days	Days
Tilia handwort	Siberia	....	....	. 25	0
Tilia parvifolia Ehr.	Europe	0	0	. 20	....
Tilia tomentosa Moench	Europe	0	0	. 10	. 19
Ulmus campestris L.	Europe & Orient	. 22	. 29	. 12	0
Ulmus effusa L.	Central & N. Europe	. 46	. 58	* 4	* 8
Ulmus montana With.	Europe & Asia	. 28	. 88	* 4	* 8
Vaccinium amoenum Ait.	N. America	. 21	. 48	. 4	. 10
Vergilia lutea Mx.	N. America	0	0	. 32	. 37
Viburnum Lantana L.	Europe & Orient	....	....	. 7	. 9
Viburnum Opulus L.	Siberia, E. Asia & Amer...	. 26	. 34	. 7	. 14
Vitex Agnus-castus L.	Europe & Orient	. 14	. 88	. 9	. 15
Vitis riparia Michx.	N. America	. 34	. 39	. 11	0
Vitis vinifera L.	Orient	....	....	. 12	. 20
Weigela rosea Ldl.	Japan	. 8	. 15	. 9	. 14
Xanthoceras sorbifolia Bunge	China	0	0	0	0
Zanthorrhiza alpiifolia L'Herit	N. America	* 2	* 88	* 4	* 9
Zanthoxylum fraxineum Willd.	N. America	* 36	* 41	* 5	. 13

A study of Table I shows the following results: Of the 234 species collected October 28 to November 4, 1905, a little more than half grew—that is, 125, while the remaining 109 made no growth.

The most of those that grew were European and Asiatic forms.

Of those that made no growth there were about equal numbers of American and European species, with also several from Asia, Japan, etc.

During the first nine days 42 species grew—that is, 18 per cent, those of European and Asiatic origin predominating, followed by American, Japanese and North African species in the order mentioned.

Of those collected in midwinter—January 8-10, 1906—the following results were taken from the table: There was a total of 283 species, of which 86 per cent—244, grew and 39 made no growth.

In the first nine days 142 species, that is, 50 per cent, grew, the highest number being of Asiatic origin, with European, American and Japanese forms following.

Since many kinds failed to grow in the two tests and a large number made but a slight growth, another set was collected on February 26, 1906. There was a total of 63 kinds in this list. In the same table—in the last two columns—is also the record of 10 more species brought in the 17th of March. This list was mainly those that made no growth in the immediately preceding test.

Table II contains the record of the collections of February 26 and March 17.

TABLE II.

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Feb. 26, 1906.		Collected March 17, 1906.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days
Acer campestre L.	Europe & Orient	....	....	. 2	0
Acer campestre L., var. pulverulentum	Hort. form	....	....	. 8	0
Acer negundo L. var., crispum	N. Amer.	. 2	. 5	....	....
Acer Pseudo-Platanus L.	Europe	. 4	0	....	....
Acer spicatum Lam.	N. Amer.	. 8	. 7	....	....
Aesculus flava Ait.	N. Amer.	. 4	. 12	....	....
Aesculus humilis Lindl.	N. Amer.	. 8	0	....	....
Alnus viridis DC.	Europe, Asia & N. Amer.	. 15	* 22	. 3	. 24
Amorpha canescens Nutt.	N. Amer.	. 25	. 34	....	....
Amorpha fruticosa L.	N. Amer.	. 15	. 25	....	....
Azalea mollis Blume	China & Japan	. 8	. 11	....	....
Benzoin odoriferum Nas.	N. Amer.	. 8	. 13	....	....
Calycanthus floridus L.	N. & S. Carolina	. 3	. 8	....	....
Carya aquatica Nutt.	N. Amer.	0	0	. 3	0
Carya porcina Nutt.	N. Amer.	. 8	0	. 4	0
Castanea vesca Grtn.	S. Europe	. 3	. 12	....	....
Cercis canadensis L.	N. Amer.	. 8	. 8	....	....
Cercis Siliquastrum L.	Europe & Orient	. 5	. 8	....	....
Chionanthus fragrans Lindl.	N. America	. 2	0	....	....
Clethra acuminata Michx.	N. America	. 8	. 9	....	....
Colutea arborescens L.	Europe & Orient	0	0	....	....
Crataegus macracantha Lodd.	N. America	. 8	. 12	....	....
Cytisus laburnum L.	Europe	. 3	. 5	....	....
Diervilla canadensis Willd.	N. America	0	0	. 8	. 15
Diospyros virginiana L.	N. America	. 3	. 8	....	....
Elaeagnus argentea Pursh.	N. America	. 8	0	....	....
Erica carnea L.	S. Europe	0	0	....	....
Euonymus americana L.	N. America	. 7	. 19	....	....
Fagus sylvatica L.	Europe & W. Asia	. 27	0	. 20	. 29
Fraxinus americana L.	N. America	. 8	. 63	. 2	. 7
Fraxinus excelsior L.	Europe & W. Asia	. 11	0	. 8	. 22
Fraxinus oregona Nutt.	N. America	. 6	. 11	....	....
Fraxinus Ornus L.	S. Europe	0	0	0	0
Hamamelis virginiana L.	N. America	. 5	. 8	....	....
Hydrangea radiata Walt.	N. America	. 2	. 6	....	....
Jasminum fruticans L.	S. Europe, N. Afr. & Orient.	. 1	. 5	....	....
Juglans regia L.	Europe & Asia	. 6	. 12	....	....
Kalmia angustifolia L.	N. America	* 8	0	....	....

TABLE II. (*Continued.*)

Twigs brought into the greenhouse without previous treatment.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Collected Feb. 26, 1906.		Collected March 17, 1906.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days
Koelreuteria paniculata L.	China	. 3	. 8	....	....
Ledum latifolium Jacq.	N. America	. 2	. 12	....	....
Liriodendron tulipifera L.	N. America	. 6	. 12	....	....
Myrica Gale L.	Europe & N. America	* 3	* 6	....	....
Ostrya vulgaris Willd.	S. Europe & Orient	. 3	. 8	....	....
Ptelea trifoliata L.	N. America	. 7	. 34	....	....
Pyrus Aria, var., edulis Ehr.	Europe & Asia	. 3	. 11	....	....
Quercus alba L.	N. America	. 6	0	....	....
Quercus ambigua W.	N. America	. 8	0	....	....
Quercus Cerris L.	S. Europe & Asia	. 6	. 13	....	....
Quercus coccinea Wang.	N. America	. 7	0	....	....
Quercus Dshorochensis C. Koch.	Europe	. 7	0	....	....
Quercus imbricaria Michx.	N. America	. 6	. 11	....	....
Quercus macranthera F. & M.	Caucasus	. 12	. 16	....	....
Quercus macrocarpa Michx.	N. America	. 11	. 20	....	....
Quercus olivaeformis Michx.	N. America	. 12	. 20	....	....
Rhododendron ponticum, var. Cunninghami L.	S. Europe & Asia Minor	. 11	0	....	....
Robinia Psued-acacia L.	N. America	. 6	. 18	....	....
Robinia Pseud-acacia, var. semperflorens L.	N. America	. 3	. 9	....	....
Salisburia adiantifolia Sm.	China & Japan	. 3	. 12	....	....
Sorbus Japonica L.	China & Japan	. 6	. 11	....	....
Tilia alba Ait.	N. America	. 3	. 12	....	....
Tilia argentea DC.	Europe	. 2	. 8	....	....
Tilia euchlora C. Koch.	Orient	. 3	. 8	....	....
Tilia handwort	Siberia	. 8	. 16	....	....
Vitis riparia Michx.	N. America	. 3	. 19	....	....
Xanthoceras sorbifolia Bunge	China	. 8	0	....	....

Of the list of 63 kinds collected February 26 (Table II), all grew but 5. At this time growth occurred in most instances very quickly, 49 having begun to grow during the first nine days, and 7 more within the second nine days, thus leaving but two more to occupy a longer time for growth. The American species, on the average, were later in beginning to grow than either the Asiatic or European.

The final test consisting of ten species, collected March 17, repsented mainly those that had not grown before. Nine of the number grew.

TREATMENTS FOR FORCING GROWTH.

2. *The Use of Ether Only* (Tables III, IV and V).

Time of treatment, from November 17 to 24, 1905.

Treated with ether only, as follows:

Etherized 48 hours
" 48+48 hours
" 72 hours
Control.

It should be explained that "48+48" means that the plants were exposed to the ether fumes for 48 hours, removed to the greenhouse and kept standing in water for 48 hours and then returned to the ether vapor for another 48 hours.

While being etherized the twigs were not kept in water, merely being enclosed in the large jars just as they came from the garden. It probably would have been better to have had the plants in water during the longer periods of etherization, but as ether vapor is readily absorbed by water, it was not practicable to do so.

During treatment the jars containing the twigs were on the floor between two windows and in this place the temperature at night sometimes fell as low as 17° or even 16°. The usual temperature, however, was between 18° and 20° C.

This was the first attempt to force growth. The list treated numbered 56 species. Here as before, figures given in the table refer to number of days required for growth to begin and for buds to open. The same characters are also used to indicate whether the growth was for a leaf bud or a flower bud. The details follow in Table III:

Treated with ether only from November 17-24, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Control.		Etherised 48 hours.		Etherised 48 + 48 hours.		Etherised 72 hours.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days	Days	Days	Days	Days
Aesculus Hippocastanum L.	Orient	0	0	* 23	0	. 21	* 39	* 22	* 32
Amelanchier ovalis Lindl.	N. America	* 18	0	. 4	0	* 1	0	* 3	0
Amelanchier vulgaris Moench.	S. Europe	0	0	. 16	0	* 6	0	0	0
Broussonetia papyrifera Vent.	China & Japan	* 12	* 17	. 4	0	. 3	0	. 6	0
Calophaca wolgarica Fisch.	S. Russia	. 8	. 18	. 4	. 10	* 6	. 14	. 4	. 9
Caragana arborescens Lam.	Siberia	. 8	0	. 4	. 10	. 1	0	. 4	* 10
Castanea pumila Michx.	N. America	0	0	0	0	0	0	. 21	. 27
Castanea vesca Grtn.	S. Europe	. 25	. 34	0	0	0	0	. 15	. 25
Cercis canadensis L.	N. America	. 17	0	0	0	. 7	0	0	0
Colutea arborescens L.	Europe & Orient	0	0	. 4	0	0	0	0	0
Cornus Mas. L.	Cent. & S. Europe	* 11	* 14	. 10	0	. 7	. 18	. 10	. 15
Crataegus macracantha Lodd.	N. America	0	0	* 40	0	0	0	0	0
Crataegus Oxyacantha L.	Europe	0	0	. 2	. 10	* 3	0	. 10	0
Crataegus spinosissima Lodd.	Siberia	0	0	. 1	. 11	0	0	. 6	. 15
Cydonia japonica Pers.	Japan	. 5	. 8	0	0	. 7	. 12	0	0
Cydonia vulgaris L.	S. Europe	. 10	. 18	. 1	. 15	0	0	. 10	. 18
Cytisus weldeni Vis.	S. Hungary	* 7	0	0	0	0	0	* 4	0
Ginkgo biloba L.	Japan	0	0	* 25	* 43	* 34	* 45	0	0
Halimodendron argentium Fisch.	Siberia & Tar.	. 8	. 21	. 5	. 12	. 3	. 8	. 4	0
Magnolia Soulangeana Soul.	Japan	. 17	. 34	. 5	0	* 5	* 12	. 11	. 15
Platanus orientalis L.	Europe & Orient	. 29	0	. 21	* 27	* 18	* 26	. 4	. 17

TABLE III. (*Continued.*)

Treated with ether only from November 17-24, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Control. Growth began in	Control. Buds fully open in	Etherised 48 hours. Growth began in	Etherised 48 hours. Buds fully open in	Etherised 48 + 48 hours. Growth began in	Etherised 48 + 48 hours. Buds fully open in	Etherised 72 hours. Growth began in	Etherised 72 hours. Buds fully open in
		Days	Days	Days	Days	Days	Days	Days	Days
Prunus Armeniaca L.	Caucasus	* 12	0	0	0	* 11	0	. 10	0
Prunus padus L.	Europe & Asia	0	0	* 2	0	* 1	0	* 4	0
Prunus serotina Ehr.	N. America	* 10	0	* 5	* 14	* 1	. 13	* 4	0
Prunus virginiana L.	N. America	. 28	. 29	. 4	. 10	. 4	. 10	* 5	0
Pyrus americana DC.	N. America	0	0	0	0	0	0	. 14	. 18
Pyrus Aria, var. edulis Ehr.	Europe & Asia	. 54	. 59	* 39	0	0	0	0	0
Pyrus aucuparia Ehr.	Europe & Asia	. 28	. 30	. 5	. 15	. 8	. 8	. 4	. 6
Pyrus malus L.	Europe & Asia	* 13	. 30	* 10	0	. 7	. 15	* 9	0
Pyrus microcarpa DC.	N. America	. 39	. 45	0	0	. 21	. 27	. 11	. 15
Pyrus prunifolia Willd.	Siberia	. 14	. 21	. 10	. 18	. 8	. 11	. 4	. 15
Quercus ambigua W.	N. America	0	0	0	0	. 11	. 25	0	0
Quercus Dahorochensis C. Koch.	Europe	. 25	. 33	0	0	0	0	. 12	. 19
Quercus macranthera F. & M.	Caucasus	0	0	. 22	0	. 11	. 21	0	0
Quercus macrocarpa Michx.	N. America	. 45	0	. 29	0	0	0	0	0
Quercus ramosa Booth	N. America	. 43	0	. 23	. 31	0	0	0	0
Rhododendron ponticum, var. Cunninghami, L.	S. Europe & Asia Minor	0	0	. 16	. 19	0	0	0	0
Robinia Pseud-acacia, var. amorphaefolia L.	N. America	. 16	. 20	. 10	0	. 6	0	. 8	. 14
Sorbus graeca Lodd. & Steud.	Europe & Asia	0	0	. 28	. 55	0	0	. 14	. 29
Spiraea Lindleyana Wall.	Asia	. 8	. 18	. 8	. 14	. 8	. 11	. 8	. 13
Spirea sorbifolia L.	Asia	. 6	. 7	. 1	. 3	. 1	. 1	. 2	. 3
Tilia argentea DC.	Europe	0	0	. 11	0	. 26	0	0	0

Fifty-six species were treated with ether in Table III, of which 42 grew and 14 did not. Only the 42 that grew were included in the table. The fourteen that did not grow were the following:

Amelanchier canadensis Medic., North Amer.
Amorpha canescens Nutt., North Amer.
Amorpha fruticosa L., North Amer.
Cercis Siliquastrum L., Europe and Orient.
Catoneaster vulgaris Lal., Europe and Orient.
Erica carnea L., South Europe.
Fagus sylvatica L., Europe and North Asia.
Gleditschia triacanthos L., North Amer.
Ostrya vulgaris Willd., South Europe and Orient.
Prunus Persica Stokes, Asia.
Quercus alba L., North Amer.
Quercus olivaeformis Michx., North Amer.
Quercus pubescens W., Europe and Asia.
Vergilia lutea Mx., North Amer.

Of the 42 species that grew all made some growth from one or more of the treatments, while only a little more than half (64.2%) of the same species grew without treatment.

A clearer idea of the outcome of this experiment will be gained from the following brief summary which shows in condensed form the results of all of the treatments on the entire 56 species, with the control included for comparison:

TABLE IV.

Summary of Table III. Fifty-six species; treated, November 17-24, 1905.

TREATMENT.	Average length of time required to begin growth.	Average length of time required for buds to open fully.	Percentage that grew.	Percentage that opened their buds fully.
	Days.	Days.		
Control	18.5	22.5	48.2	32.1
Etherized 48 hrs.	12.0	18.6	56.0	30.3
Etherized 48 + 48 hrs.	8.2	14.2	50.0	32.1
Etherized 72 hours.........	8.8	16.3	50.0	33.9

The marked effects of the ether are seen in the larger percentage that grew when treated, and especially in the shorter time required for growth to begin. A gain in time of growth of more than ten days followed the 48+48 hours and the 72 hours treatments, while there was but 6.5 days gain from the 48 hours treatment. Etherizing for 48+48 hours gave the best results in this test.

While the summary just given shows the average time required for growth to begin under each treatment, it does not show the true effects of treatments in their proper relations. The chief defect lies in the fact that, of necessity, direct comparison was made between easily reacting species and those that grew with great difficulty even under severe treatment. For example, in the control *Cydonia japonica* grew first in five days, while *Pyrus aria,* variety *edulis,* also untreated, did not begin to grow until fifty-four days had elapsed. And, when treated with ether for forty-eight hours, *Pyrus aria,* var. *edulis,* required thirty-nine days to begin growth, while the *Cydonia vulgaris,* under the same treatment, grew in one day. Manifestly, then, it is unfair and does not show the exact or anywhere near the exact state of affairs in either case to take an average between the five days and fifty-four days, in the one instance, or the one day and the thirty-nine days in the other. This had to be done, however, in order to reduce the results to a form brief enough to admit of easy comparisons. The summary referred to serves its purpose but realizing its defects another review was prepared as follows:

TABLE V.

Second Summary of Table III, showing the extent of growth at the end of 1 wk., 2 wks., 3 wks., and, after 3 weeks.

TREATMENT.	Percentage that began growth in				Percentage that opened their bud fully in			
	1 week.	2 weeks.	3 weeks.	More than 3 weeks.	1 week.	2 weeks.	3 weeks.	More than
Control	11.1	44.4	11.1	33.6	5.55	22.2	27.75	44.
Etherized 48 hrs.	50.0	15.62	9.37	25.0	5.88	47.05	23.52	23.
Etherized 48 + 48 hours	71.4	10.71	10.71	7.14	5.55	55.5	11.10	27
Etherized 72 hrs.	48.18	41.26	6.88	3.44	10.53	26.32	42.10	21.

In this second summary just given the number of days elapsing before growth began was divided into groups or periods. The shortest period was one week, that is, all that began to grow within seven days after treatment were grouped together and in like manner all that grew inside of two weeks, three weeks, and those requiring more than three weeks respectively were grouped together.

This method shows some results not brought out before. For instance, in the first summary the effects from etherizing 48+48 hours and of 72 hours appear to be practically the same (8.2 and 8.3 days), but in the second or more detailed review it is seen that of those treated for 48+48 hours 71.4 per cent grew inside of seven days, while of those etherized 72 hours only 48.13 per cent grew in the same length of time. This means that the ether acting continuously through a long period of time, although seemingly as effective as the 48+48 hours treatment, did not cause a quick growth in as large a number of plants as the latter. It is furthermore plainly shown that 48+48 hours of ether caused practically all the number in the list to begin growth during the first week after treatment while those etherized 72 hours required two weeks for accomplishing the same results. On the other hand, the untreated plants and those receiving 48 hours of ether were slow in starting into growth, one-third of the former and one-fourth of the latter beginning to grow after three weeks from date of treatment.

Regarding the effects of the treatments on the time required for the buds to fully open, it is noticed that at the end of three weeks almost half of the controls had not opened, while at the same time a much smaller number of the treated ones were not yet out. It is further interesting to follow all the way through the effects of etherizing for 48+48 hours. Although nearly three-fourths of the species began to grow inside of one week, one-fourth of the buds had not opened fully after three weeks. This seems to indicate that with many species the treatment may cause such a stimulus to the buds that they are quickly started into action but that the growth does not continue until the buds (flower or leaf) are fully open. Observations during experiments also confirm this.

3. *Experiments with Freezing, Etherizing and Use of Dark-Chamber* (Tables VI, VII and VIII.)

Time of treatement from November 21 to December 1, 1905. The 35 species were given the following treatments:

Frozen for 7 days;
Frozen for 21 days;
Frozen for 7 days, then etherized for 24 hours;
Frozen for 21 days, then etherized for 48 hours;

In the moist, dark-chamber for 8 days;
In the moist, dark-chamber for 17 days;
Control.

This was the second attempt to force growth. Ether alone having been found to be effective in awakening many plants from their dormant state, two new methods of treatment—freezing and confining plants in a moist, dark-chamber, were introduced. It was desired also to find if the ether would exert any more influence when used immediately after the plants were severely frozen than would the freezing alone. The dark-chamber supplied two conditions not present in the greenhouse, viz., uniform temperature and high, constant humidity.

In Table VI, which follows, are to be seen in detail the results of all the treatments:

Treated between November 21 and December 1, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Control.		Frozen 7 days.		Frozen 21 days.		Frozen 7 days; Etherized 24 hours.		Frozen 7 days: Etherized. 48 hours.		Dark Chamber 8 days.		Dark Chamber 17 days.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days
Acer macrophyllum Pursh.	N. America	0	0	0	0	0	0	0	0	0	0	. 41	: 45	0	0
Acer platanoides L.	Europe	0	0	0	0	. 20	. 35	. 41	. 53	0	0	. 48	. 55	. 42	0
Aesculus Hippocastanum L.	Orient	* 21	* 33	. 31	. 44	. 22	. 35	. 22	. 32	. 19	. 26	. 15	. 29	. 15	* 30
Alnus barbata C. A. Mey	Caucasus	. 22	. 27	0	0	0	0	0	0	0	0	0	0	0	0
Amorpha canescens Nutt.	N. America	* 21	* 29	0	0	* 23	. 36	0	0	0	0	* 24	. 45	. 23	. 29
Amygdalus communis L.	Orient	. 9	. 13	. 5	* 19	. 7	* 15	. 6	. 12	. 3	. 9	0	0	0	0
Azalea pontica L.	Asia Minor	* 26	* 37	. 35	. 58	0	0	0	0	0	0	. 9	. 13	. 39	* 44
Betula alba L.	Europe & Asia	. 17	. 23	. 11	. 18	. 13	* 13	. 6	. 18	. 4	. 9	. 11	. 15	. 11	. 15
Caragana arborescens Lam.	Siberia	. 9	0	. 4	. 11	0	0	. 3	0	. 3	0	0	0	0	0
Carpinus americana Michx.	N. America	0	0	. 35	. 45	0	0	. 31	. 41	. 19	. 27	0	0	0	0
Cornus Mas L.	Europe	* 9	* 11	* 4	* 7	* 1	* 7	* 10	0	. 11	. 17	* 11	* 15	* 11	* 15
Corylus Colurna L.	Asia Minor	0	* 15	0	0	0	0	0	0	0	0	0	* 19	0	* 19
Crataegus macracantha Lodd.	N. America	. 53	0	0	0	0	0	. 33	. 43	0	0	0	0	. 52	0
Gleditschia triacanthos L.	N. America	. 11	. 16	0	0	0	0	0	0	0	0	. 12	0	0	0
Populus candicans Ait.	Asia & N. Amer.	. 19	. 25	. 13	. 18	. 15	. 19	. 13	. 18	* 4	* 9	. 24	. 27	. 22	. 25
Populus monilifera Rozier	N. America	. 33	. 42	. 26	. 33	. 21	. 33	. 26	. 32	. 23	. 29	. 27	. 33	. 21	. 25
Prunus cerasus L.	Asia Minor	* 11	* 16	* 5	. 19	. 5	. 14	. 3	. 18	* 4	. 17	* 10	. 19	* 9	. 18
Prunus domestica L.	Caucasus	0	0	0	0	. 16	. 23	0	0	0	0	0	0	0	0
Prunus virginiana L.	N. America	. 25	. 31	* 17	0	* 21	0	* 6	. 22	0	0	* 29	0	* 39	0
Pyrus cerasifera Tausch.	Asia Minor	. 9	. 15	. 13	. 20	. 24	. 35	. 13	. 18	. 5	. 16	* 11	0	. 11	. 81

TABLE VI. (*Continued.*)

Treated between November 21 and December 1, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

SPECIES.	HABITAT.	Control.		Frozen 7 days.		Frozen 21 days.		Frozen 7 days; Etherized 24 hours.		Frozen 7 days; Etherized. 48 hours.		Dark Chamber 8 days.		Dark Chamber 17 days.	
		Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in	Growth began in	Buds fully open in
		Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days	Days
Pyrus communis L.	Europe & Asia	* 9	. 15	* 6	. 19	. 5	. 18	* 7	. 14	* 8	. 19	. 6	. 14	. 6	. 14
Pyrus malus L.	Europe & Asia	. 11	. 16	. 18	. 18	. 23	0	. 9	. 18	0	0	. 11	. 18	. 11	. 17
Pyrus microcarpa DC.	N. America	. 21	. 28	. 15	. 23	. 20	. 27	. 14	. 22	. 10	. 18	* 15	. 26	. 16	. 28
Pyrus prunifolia Willd.	Siberia	. 11	. 16	. 12	. 22	. 5	. 18	. 6	. 12	. 8	. 16	. 12	. 17	. 12	. 19
Quercus Dahorochensis C. Koch.	Europe	* 17	0	0	0	0	0	0	0	0	0	0	0	0	0
Robinia Pseud-acacia, var. amorphaefolia L.	N. America	0	0	0	0	0	0	0	0	0	0	0	0	. 19	. 25
Salix alba vitellina pendula L.	Asia & Africa	. 7	. 11	. 6	. 9	. 6	. 10	. 8	. 8	. 9	. 18	. 8	. 9	. 8	. 9
Sophora Japonica L.	Japan & China	0	0	0	0	0	0	. 18	. 17	0	0	. 14	. 18	0	0
Sorbus graeca Lodd. & Steud.	Europe & Asia	0	0	0	0	0	0	. 29	. 37	. 27	. 36	0	0	. 46	. 51
Syringa vulgaris L.	Orient	. 17	. 29	. 6	. 12	. 10	. 14	. 5	. 9	0	0	. 18	. 28	0	0
Vergilia lutea Michx.	N. America	0	0	0	0	0	0	. 38	. 42	. 14	. 20	0	0	0	0
Viburnum Lantana L.	Europe & Orient	. 26	. 29	. 7	. 12	0	0	. 22	0	0	0	. 28	. 31	. 27	. 29

In Table VI, only three species out of the 35 made no growth whatever:

Acer dasycarpum Ehr., North Amer.,
Amorpha fruticosa L., North Amer., and
Fagus sylvatica L., Europe and W. Asia.

Of the 32 species given in Table VI, 93.7 per cent grew from one or more treatments, while only 65.7 per cent grew without treatment. A fairer method of considering the results would be to compare the control with each of the treatments separately. This method will give the relative merits of each treatment while comparing the control with all of the treatments merely shows in general that the sum of many conditions gave better results than one condition.

In the last table only the 32 species that grew were given but in the following summary of Table VI, all the 35 species treated are considered, including the control:

TABLE VII.

Summary of Table VI. Thirty-five species; treated between November 21 and December 1, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.	Average length of time required for beginning growth.	Average length of time required for buds to open fully.	Percentage that grew.	Percentage that opened their buds fully.
	days.	days.		
1 Control	18.0	21.7	65.7	60.0
2 Frozen 7 days	14.4	22.6	54.2	51.4
3 Frozen 21 days	14.2	21.3	51.4	45.7
4 Frozen 7 days; etherized 24 hours	15.6	24.3	65.7	57.1
5 Frozen 7 days; etherized 48 hours	10.3	18.7	45.7	42.8
6 In moist dark chamber 8 days	17.7	24.7	60.0	54.2
7 In moist dark chamber 17 days	21.7	24.6	57.1	51.4

The review shows some very interesting results. No. 5 made the quickest growth, average 10.3 days, a gain over the control of 7.7 days.

Freezing for one week and for three weeks (No. 2 and No. 3) caused about the same results in length of time required for growth and the percentage that grew.

Comparing No. 2 and No. 4 it is seen that the addition of the ether did not hurry the growth but the increase in the number of those that grew was more than 11 per cent.

Comparing 3 and 5, similar treatments except for the ether, the anesthetic seems to have exerted an extraordinary effect in two ways: first, the time was much shortened; and, second, a smaller percentage grew.

In every treatment but one—No. 4—a smaller percentage grew than the untreated. On the other hand, every treatment but one—No. 7—caused a quicker growth than the control.

It will further be noticed that the treatment giving the shortest time for growth (No. 5, gain 7.7 days) shows the *smallest* number that grew, loss 20 per cent! This is true in less degree with nearly all of the treatments.

Evidently freezing, followed by strong etherization, exerts a profound influence on dormant plants, causing them either to grow and grow quickly or to be killed or severely injured. There was little evidence of any of the plants remaining indifferent to the treatments.

More than half of the species grew without treatment—65.7 per cent. In no case did a treatment cause a larger percentage of growth than the untreated and only in one instance—No. 4—was it equaled.

Those species that grew without treatment and also many that forced easily, were often injured by the severe treatments. In other words, they responded readily to the treatments, but when prolonged, as in No. 5, many were killed and thus the percentage that grew would be very small. This is the explanation for the small percentage, in general, of the treated ones that grew. No. 4, however, seems to have been an exception.

Below will be seen a second summary of the last experiment in which the time required for growth to begin is again divided into weekly periods up to three weeks, when all that grew after that are grouped under the heading of "more than 3 weeks."

TABLE VIII.

Second Summary of Table VI, showing the extent of growth at the end of 1 wk., 2 wks., 3 wks., and, after 3 wks.

TREATMENT.	Percentage that began growth in 1 week.	2 weeks.	3 weeks.	More than 3 weeks.	Percentage that opened their buds fully in 1 week.	2 weeks.	3 weeks.	More than 3 weeks.
1 Control	4.35	39.12	30.43	26.08	0	15.79	36.85	57.89
2 Frozen 7 days	42.10	26.31	10.53	21.05	5.55	22.20	38.85	33.30
3 Frozen 21 days	33.30	11.10	33.30	22.20	5.88	35.29	11.76	47.05
4 Frozen 7 days; etherized 24 hours	39.12	26.08	0	34.78	0	25.0	30.0	45.0
5 Frozen 7 days; etherized 48 hours	43.75	31.25	12.50	12.50	6.67	26.66	46.67	26.66
6 Dark Chamber 8 days	9.52	47.61	9.52	33.33	0	15.79	36.84	47.37
7 Dark Chamber 17 days	10.0	30.0	20.0	40.0	0	11.10	33.30	55.50

The most noticeable thing about this review is the large percentage that made a quick growth from treatment No. 5 (frozen 7 days then etherized 48 hours). This was the treatment that caused growth in the shortest average length of time, and it is now found—as before—that the first week saw the beginning of growth in a great majority of the species. Unlike the previous experiment, however, the growth in this case was not of a temporary nature, but continued until the buds were fully open.

A queer feature brought out by the table was the behavior of those frozen seven days. Just why a large percentage of the species should have made a quick growth there is not clear when the average number of days required for growth, as shown in Table VII, was 14.4 days or 4.1 days more than the No. 5 treatment.

Taking up the first column in the summary, the percentage of species that grew inside of one week, and comparing the control with each of the others the full effects of the different treatments are seen in a striking manner.

4. *Experiment in Etherizing, Drying, Freezing and Dark-Chamber, Singly and in Combination* (Tables IX, X and XI).

Date of treatment December 8 to 23, 1905; number of species 70.

The treatments were as follows:

Etherized 48 hours;
Etherized 48+48 hours;
Dried 1 day;
Dried 2 days;
Dried 3 days;
Dried 4 days;
Dried 5 days;
Frozen 8 days;
Frozen 14 days;
Confined in dark-chamber 8 days;
Confined in dark-chamber 14 days;
Frozen 8 days, then etherized 48 hours;
Frozen 8 days, then etherized 72 hours;
Frozen 8 days, then in dark-chamber 5 days;
In dark-chamber 8 days, then etherized 48 hours;
In dark-chamber 8 days, then etherized 72 hours;
Control.

This was the last of the three main sets of treatments, and was by far the largest of them all, both in point of number of species used and the number of treatments employed. Ether and freezing, singly and in combination, having proved beneficial in forcing growth and an independent test in drying (not shown here—see page 78) having shown some interesting results, it was desired to compare the effects of these three treatments in particular. At the same time the dark-chamber was tried again by itself and also followed by etherization. The full results are given in detail in Table IX which follows:

TABLE IX.

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Acer campestre L. Europe & Orient.	Acer campestre L., var. pulverulentum. Hort. form.
		Days.	Days.
Control	Began growth in	. 20	0
	Buds fully open in	. 25	0
Etherized 48 hours	Began growth in	0	. 9
	Buds fully open in	. 0	. 32
Etherized 48 + 48 hours	Began growth in	0	. 12
	Buds fully open in	0	0
Dried 1 day	Loss of weight	4.60%	9.52%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 2 days	Loss of weight	6.85%	8.97%
	Began growth in	. 17	0
	Buds fully open in	0	0
Dried 3 days	Loss of weight	9.56%	11.26%
	Began growth in	* 14	* 17
	Buds fully open in	0	0
Dried 4 days	Loss of weight	12.15%	16.66%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 5 days	Loss of weight	14.92%	18.60%
	Began growth in	* 9	0
	Buds fully open in	. 21	0
Frozen 8 days	Began growth in	. 26	. 14
	Buds fully open in	0	0
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	. 20	. 30
	Buds fully open in	. 27	. 38
In dark chamber 14 days	Began growth in	. 28	. 24
	Buds fully open in	0	. 37
Frozen 8 days; etherized 48 hours	Began growth in	. 30	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	0	. 10
	Buds fully open in	0	. 16
Frozen 8 days; in dark chamber 5 days	Began growth in	. 26	0
	Buds fully open in	0	0
Dark chamber 8 days; etherized 48 hours	Began growth in	. 22	. 17
	Buds fully open in	0	. 34
Dark chamber 8 days; etherized 72 hours	Began growth in	0	. 26
	Buds fully open in	0	. 32

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Acer dasycarpum Ehr. N. America.	Acer monspessulanum L. S. Europe.
		Days.	Days.
Control	Began growth in	. 25	0
	Buds fully open in	0	0
Etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Etherized 48 + 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Dried 1 day	Loss of weight	4.60%	4.95%
	Began growth in	* 15	0
	Buds fully open in	* 22	0
Dried 2 days	Loss of weight	7.14%	8.91%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 3 days	Loss of weight	9.84%	12.90%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 4 days	Loss of weight	21.31%	15.17%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 5 days	Loss of weight	23.26%	21.90%
	Began growth in	* 12	0
	Buds fully open in	* 18	0
Frozen 8 days	Began growth in	0	0
	Buds fully open in	0	0
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 14 days	Began growth in	0	. 18
	Buds fully open in	0	. 25
Frozen 8 days; etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	0	0
	Buds fully open in	0	0
Dark chamber 8 days; etherized 48 hours	Began growth in	0	. 23
	Buds fully open in	0	0
Dark chamber 8 days; etherized 72 hours	Began growth in	. 39	. 20
	Buds fully open in	. 47	. 30

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Acer negundo L., var. californicum. California.	Acer negundo L., var. versicolor. N. America.	Acer negundo L. var. violaceum. N. America.	Acer Pseudo-Platanus L. Europe.	Acer spicatum Lam. N. America.	Acer Tataricum L. S. E. Europe.
Days.	Days.	Days.	Days.	Days.	Days.
0	. 33	. 39	0	0	. 27
0	. 43	. 45	0	0	. 36
. 17	0	. 9	. 18	. 10	. 8
. 24	0	. 25	0	. 22	0
. 7	0	. 17	* 11	. 7	0
. 30	0	0	* 18	. 22	0
5.60%	3.77%	4.13%	6.90%	7.31%	7.72%
. 43	. 31	. 34	* 20	0	* 12
0	. 43	0	* 29	0	* 21
7.18%	9.34%	6.33%	8.45%	9.19%	11.76%
. 48	.29	. 37	0	0	* 11
0	. 42	0	0	0	* 20
12.31%	14.96%	6.07%	3.41%	12.64%	16.82%
. 15	.21	. 32	* 16	0	0
. 28	. 32	0	* 24	0	0
12.73%	16.66%	14.45%	11.04%	14.15%	17.93%
. 47	. 16	. 23	. 14	0	0
. 52	. 28	0	. 39	0	0
10.52%	19.65%	17.64%	15.66%	12.50%	19.0%
. 34	. 12	. 17	0	. 18	0
0	. 20	. 25	0	. 26	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
. 35	0	. 26	0	0	* 21
0	0	. 36	0	0	0
. 30	. 32	. 23	0	. 24	* 22
. 37	0	. 37	0	0	0
. 13	. 13	. 13	0	0	0
0	0	0	0	0	0
. 11	0	. 10	0	. 10	0
. 24	0	0	0	0	0
0	0	. 16	0	0	0
0	0	0	0	0	0
. 20	. 32	. 20	. 21	. 19	. 8
0	0	. 34	0	. 25	0
. 20	0	. 21	0	. 18	0
. 34	0	0	0	. 24	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Acer tauricum. Europe & Orient.	Aesculus flava Ait. N. America.
		Days.	Days.
Control	Began growth in	. 19	0
	Buds fully open in	. 33	0
Etherized 48 hours	Began growth in	0	. 49
	Buds fully open in	0	0
Etherized 48 + 48 hours	Began growth in	0	. 39
	Buds fully open in	0	0
Dried 1 day	Loss of weight	4.04%	3.12%
	Began growth in	0	. 50
	Buds fully open in	0	. 56
Dried 2 days	Loss of weight	6.31%	8.67%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 3 days	Loss of weight	9.89%	8.33%
	Began growth in	0	. 50
	Buds fully open in	0	0
Dried 4 days	Loss of weight	11.21%	8.83%
	Began growth in	0	. 49
	Buds fully open in	0	0
Dried 5 days	Loss of weight	....	13.85%
	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days	Began growth in	. 20	0
	Buds fully open in	. 29	0
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	. 23	0
	Buds fully open in	0	0
In dark chamber 14 days	Began growth in	. 19	0
	Buds fully open in	. 27	0
Frozen 8 days; etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	0	0
	Buds fully open in	0	0
Dark chamber 8 days; etherized 48 hours	Began growth in	. 19	0
	Buds fully open in	. 25	0
Dark chamber 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Alnus Americana C. Koch. N. America.	Alnus glutinosa Medic. Europe, Asia, Africa & N. America.	Andromeda Japonica Thunbg. Japan.	Andromeda paniculata L. N. America.	Azalea mollis Blume. China & Japan.	Azalea pontica L. Asia Minor.
Days.	Days.	Days.	Days.	Days.	Days.
. 29	0	. 18	. 19	* 14	* 22
. 34	0	. 18	. 28	0	0
. 26	0	. 9	. 11	* 11	* 20
. 30	* 10	. 16	. 34	. 23	0
0	0	0	. 10	* 7	* 16
* 18	* 6	0	. 18	* 21	* 21
6.01%	8.40%	10.78%	3.33%	11.21%	6.12%
0	. 14	. 19	0	* 14	* 21
* 17	. 20	. 25	0	. 27	* 28
12.78%	12.96%	17.33%	10.22%	10.56%	10.06%
0	0	. 15	0	* 26	* 21
0	0	. 21	0	* 34	0
16.36%	18.25%	31.14%	6.66%	20.0%	18.68%
. 32	0	0	0	* 14	* 20
. 38	0	0	0	. 27	. 28
12.35%	20.51%	37.33%	10.27%	18.91%	14.56%
. 32	0	0	0	* 21	* 19
. 37	0	0	0	* 32	0
20.92%	16.69%		12.24%	21.92%	16.16%
. 18	0	0	0	. 13	0
. 24	0	0	0	. 25	0
0	0	0	0	* 16	0
0	0	0	0	* 28	0
0	0	0	0	0	0
0	0	0	0	0	0
. 30	. 40	0	0	* 32	* 25
. 34	. 44	0	0	* 38	0
. 38	. 44	0	. 26	* 32	* 24
. 43	0	0	0	0	. 34
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
. 15	0	0	. 19	* 27	* 22
. 21	0	0	. 35	* 34	0
0	. 28	0	0	* 30	* 22
* 22	. 31	0	0	0	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Betula nigra L. N. America.	Castanea pumila Michx. N. America.
		Days.	Days.
Control	Began growth in	. 26	0
	Buds fully open in	. 32	0
Etherised 48 hours	Began growth in	* 7	0
	Buds fully open in	* 12	0
Etherised 48 + 48 hours	Began growth in	. 4	0
	Buds fully open in	. 11	0
Dried 1 day	Loss of weight	7.95%	14.28%
	Began growth in	. 26	0
	Buds fully open in	. 37	0
Dried 2 days	Loss of weight	13.79%	10.87%
	Began growth in	. 26	0
	Buds fully open in	. 37	0
Dried 3 days	Loss of weight	14.11%	15.08%
	Began growth in	. 24	0
	Buds fully open in	. 29	0
Dried 4 days	Loss of weight	13.93%	12.72%
	Began growth in	. 24	0
	Buds fully open in	. 33	0
Dried 5 days	Loss of weight	20.77%	19.58%
	Began growth in	. 21	0
	Buds fully open in	. 27	0
Frozen 8 days	Began growth in	. 29	0
	Buds fully open in	* 34	0
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	* 22	0
	Buds fully open in	* 26	0
In dark chamber 14 days	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherised 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherised 72 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	. 30	0
	Buds fully open in	. 36	0
Dark chamber 8 days; etherized 48 hours	Began growth in	. 13	. 25
	Buds fully open in	. 21	0
Dark chamber 8 days; etherized 72 hours	Began growth in	. 12	0
	Buds fully open in	. 20	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Castanea vesca Grtn. S. Europe.	Cedrela sinensis Juss. China.	Celtis occidentalis L. N. America.	Cornus alba L. Siberia.	Cornus candidissima Mill. N. America.	Cornus Sanguinea L. Europe & Orient.
Days.	Days.	Days.	Days.	Days.	Days.
0	. 17	0	. 11	0	. 18
0	. 24	0	. 15	0	. 23
. 10	. 29	. 14	* 7	. 11	. 8
. 16	. 33	. 21	. 11	0	. 7
. 13	. 13	0	. 4	0	. 4
. 20	. 21	* 12	. 7	0	. 7
5.72%	2.69%	9.17%	9.27%	11.66%	8.60%
0	. 15	0	. 12	0	. 12
0	. 20	0	. 16	0	. 18
9.46%	4.87%	10.0%	16.77%	20.0%	12.62%
0	. 9	0	. 14	. 14	. 15
0	. 17	0	. 18	. 25	. 20
12.85%	6.84%	11.81%	17.74%	19.17%	9.74%
0	. 10	0	. 9	0	. 11
0	. 17	0	. 15	0	. 16
13.96%	7.27%	11.45%	20.58%	22.80%	19.41%
0	. 18	0	. 6	0	. 15
0	. 19	0	. 12	0	. 13
15.61%	10.88%	13.33%	12.22%	32.85%	7.84%
0	. 8	0	. 8	0	. 17
0	. 15	0	. 14	0	. 22
0	. 15	0	. 14	0	. 13
0	. 22	0	. 20	0	. 19
. 18	0	0	0	0	. 18
. 29	0	0	0	0	. 22
. 20	. 18	0	. 18	0	. 19
0	. 24	0	. 23	0	. 25
. 19	. 16	0	. 20	0	. 20
. 27	. 23	0	. 27	0	. 27
. 17	. 7	0	0	0	. 4
. 23	. 18	0	0	0	. 9
. 25	. 8	. 9	. 3	0	. 4
. 31	. 14	0	. 9	0	. 9
. 22	. 12	0	* 13	0	0
. 36	. 19	0	. 23	0	0
. 22	. 16	. 16	. 13	. 21	. 15
0	. 22	. 21	. 21	. 26	. 21
. 21	. 15	0	. 12	. 23	. 13
0	. 21	0	. 20	0	. 20

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Crataegus flava Ait. N. America.	Crataegus floribunda C. Koch. N. America.
		Days.	Days.
Control	Began growth in	. 19	. 27
	Buds fully open in	0	. 50
Etherized 48 hours	Began growth in	0	. 7
	Buds fully open in	* 19	. 17
Etherized 48 + 48 hours	Began growth in	0	. 10
	Buds fully open in	0	. 16
Dried 1 day	Loss of weight	2.69%	7.87%
	Began growth in	0	. 23
	Buds fully open in	0	. 30
Dried 2 days	Loss of weight	14.03%	12.19%
	Began growth in	0	. 15
	Buds fully open in	0	. 28
Dried 3 days	Loss of weight	15.73%	14.16%
	Began growth in	. 15	. 14
	Buds fully open in	. 24	. 25
Dried 4 days	Loss of weight	18.86%	15.04%
	Began growth in	0	. 18
	Buds fully open in	0	. 25
Dried 5 days	Loss of weight	18.39%	23.80%
	Began growth in	0	. 12
	Buds fully open in	0	. 24
Frozen 8 days	Began growth in	0	. 33
	Buds fully open in	0	0
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	. 23	. 34
	Buds fully open in	. 32	. 45
In dark chamber 14 days	Began growth in	. 35	. 31
	Buds fully open in	0	. 38
Frozen 8 days; etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	0	. 22
	Buds fully open in	0	. 38
Dark chamber 8 days; etherized 48 hours	Began growth in	. 18	. 21
	Buds fully open in	. 25	. 29
Dark chamber 8 days; etherized 72 hours	Began growth in	. 16	. 18
	Buds fully open in	. 22	. 24

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Crataegus latifolia L. N. America.	Crataegus oliverians B. & DC. Europe.	Crataegus punctata var. aurea Jacq. N. America.	Crataegus stipulaceae. Europe.	Diospyros virginiana L. N. America.	Fraxinus excelsior L. Europe & Asia.
Days.	Days.	Days.	Days.	Days.	Days.
0	. 13	. 31	0	. 9	0
* 23	0	0	0	. 14	0
. 11	* 8	. 7	. 8	. 14	0
0	0	. 17	. 25	. 22	0
. 12	0	0	. 12	0	0
0	0	0	0	0	0
6.71%	6.42%	8.77%	5.51%	5.05%	4.0%
. 25	. 15	. 22	0	. 14	0
0	. 31	. 32	0	. 27	0
8.47%	7.81%	11.90%	8.86%	11.45%	7.75%
. 20	0	0	. 22	. 14	0
0	0	0	0	. 27	0
19.81%	11.47%	16.80%	10.0%	13.29%	8.80%
. 16	. 13	0	0	. 15	0
0	. 22	0	0	. 25	0
....	17.10%	20.61%	15.49%	14.28%	12.10%
....	. 10	. 11	0	0	0
....	. 29	. 20	0	0	0
17.14%	17.40%	20.94%	21.34%	15.38%	12.58%
0	. 11	. 15	0	0	0
0	. 28	. 22	0	0	0
0	0	0	. 26	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
. 32	. 23	* 37	0	. 20	0
0	0	0	0	. 27	0
. 35	. 22	0	0	. 21	0
0	. 27	0	0	. 21	0
. 22	. 11	. 10	0	0	. 18
0	0	0	0	0	0
0	0	0	0	. 11	0
0	0	0	0	0	0
0	0	0	0	. 10	0
0	0	0	0	0	0
. 23	. 24	. 26	0	. 22	0
0	0	. 30	0	0	0
. 20	0	. 21	. 22	0	0
0	0	. 28	. 34	0	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Fraximus Ornus L. S. Europe.	Gymnocladus canadensis Lam. N. America.
		Days.	Days.
Control	Began growth in	0	. 8
	Buds fully open in	0	0
Etherized 48 hours	Began growth in	0	. 25
	Buds fully open in	0	. 30
Etherized 48 + 48 hours	Began growth in	0	. 9
	Buds fully open in	0	. 16
Dried 1 day	Loss of weight	4.11%	4.69%
	Began growth in	0	. 5
	Buds fully open in	0	. 13
Dried 2 days	Loss of weight	6.47%	7.10%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 3 days	Loss of weight	7.10%	7.08%
	Began growth in	0	. 15
	Buds fully open in	0	. 23
Dried 4 days	Loss of weight	9.08%	10.50%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 5 days	Loss of weight	11.47%	....
	Began growth in	0	....
	Buds fully open in	0	....
Frozen 8 days	Began growth in	0	. 12
	Buds fully open in	0	. 18
Frozen 14 days	Began growth in	0	. 21
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	0	. 18
	Buds fully open in	0	. 23
In dark chamber 14 days	Began growth in	0	. 16
	Buds fully open in	0	. 23
Frozen 8 days; etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	. 29	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	0	. 13
	Buds fully open in	0	. 17
Dark chamber 8 days; etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Dark chamber 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Juglans nigra L. N. America.	Liquidambar styraciflua L. N. America.	Mespilus germanica L. Europe.	Ostrya vulgaris Willd. S. Europe & Orient.	Platanus orientalis L. Europe & Orient.	Populus balsamifera Lyall. California.
Days.	Days.	Days.	Days.	Days.	Days.
. 22	. 35	. 21	0	. 22	. 16
. 31	. 45	. 23	0	. 32	. 23
. 23	0	. 6	0	. 16	. 7
. 34	0	. 12	0	. 23	. 13
. 22	. 27	. 16	. 14	. 13	. 10
. 23	. 35	0	0	. 29	. 16
3.30%	12.16%	6.83%	3.54%	6.52%	4.54%
. 31	0	. 14	0	* 17	. 12
0	0	. 23	0	* 26	. 19
5.46%	16.21%	11.46%	9.30%	11.22%	6.76%
. 29	0	. 10	. 39	* 14	. 7
. 39	0	. 18	0	0	. 19
8.53%	20.14%	12.26%	10.93%	13.65%	10.24%
. 25	0	. 10	0	0	. 11
0	0	. 17	0	0	. 18
10.23%	25.15%	15.44%	12.08%	13.96%	8.97%
0	0	0	0	* 23	. 10
0	0	0	0	. 25	. 19
9.05%	30.11%	14.77%	16.09%	20.13%	16.71%
0	0	. 9	. 14	. 0	. 10
0	0	. 15	. 29	0	. 16
0	0	. 23	0	. 23	. 14
0	0	. 35	0	. 29	. 21
0	0	0	0	. 17	. 16
0	0	0	0	0	. 21
0	0	.19	0	. 20	. 18
0	0	. 24	0	. 35	. 26
. 35	0	. 20	0	. 39	. 15
0	0	. 27	0	0	. 22
0	0	. 20	0	. 8	. 4
0	0	0	0	. 21	. 15
0	0	. 21	0	* 8	. 5
0	0	0	0	. 21	. 14
0	0	. 18	0	. 22	. 21
0	0	. 23	0	* 35	. 27
0	. 30	. 13	0	* 16	. 13
0	0	. 20	0	. 34	. 21
0	. 23	. 14	0	. 14	. 18
0	. 27	. 21	0	. 31	. 24

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Populus pyramidalis Rozier. S. Europe.	Pterocarya caucasica C. A. Mey. Orient.
		Days.	Days.
Control	Began growth in	. 9	. 24
	Buds fully open in	. 15	0
Etherized 48 hours	Began growth in	. 6	. 16
	Buds fully open in	. 11	. 23
Etherized 48 + 48 hours	Began growth in	. 7	. 12
	Buds fully open in	. 15	. 19
Dried 1 day	Loss of weight	6.04%	6.45%
	Began growth in	. 15	0
	Buds fully open in	. 20	0
Dried 2 days	Loss of weight	5.72%	9.04%
	Began growth in	. 14	0
	Buds fully open in	. 20	0
Dried 3 days	Loss of weight	8.53%	7.89%
	Began growth in	. 11	0
	Buds fully open in	. 17	0
Dried 4 days	Loss of weight	12.06%	13.20%
	Began growth in	. 14	. 25
	Buds fully open in	. 20	0
Dried 5 days	Loss of weight	16.66%	13.74%
	Began growth in	. 9	0
	Buds fully open in	. 15	0
Frozen 8 days	Began growth in	. 7	0
	Buds fully open in	. 13	0
Frozen 14 days	Began growth in	. 9	0
	Buds fully open in	. 14	0
In dark chamber 8 days	Began growth in	. 7	0
	Buds fully open in	. 13	0
In dark chamber 14 days	Began growth in	. 9	0
	Buds fully open in	. 14	0
Frozen 8 days; etherized 48 hours	Began growth in	. 6	0
	Buds fully open in	. 15	0
Frozen 8 days; etherized 72 hours	Began growth in	. 7	0
	Buds fully open in	. 13	0
Frozen 8 days; in dark chamber 5 days	Began growth in	. 14	0
	Buds fully open in	. 19	0
Dark chamber 8 days; etherized 48 hours	Began growth in	. 16	0
	Buds fully open in	. 21	0
Dark chamber 8 days; etherized 72 hours	Began growth in	. 14	. 18
	Buds fully open in	. 20	. 25

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Quercus Cerris L. S. E. Europe & Asia.	Quercus macrocarpa Michx. N. America.	Quercus olivaeformis Michx. N. America.	Quercus pedunculata, var. fastigiata W. Europe.	Quercus ramosa Booth. N. America.	Quercus rubra L. N. America.
Days.	Days.	Days.	Days.	Days.	Days.
. 22	0	0	. 21	. 33	. 34
. 29	0	0	. 27	0	. 44
. 20	0	0	. 7	. 18	0
. 32	0	0	. 15	0	0
. 17	0	0	0	0	0
. 26	0	0	0	0	0
9.38%	3.72%	6.47%	6.21%	....	7.10%
0	. 35	. 26	0	....	0
0	. 46	0	0	....	0
14.63%	7.20%	9.01%	12.06%	10.48%	9.23%
. 21	. 40	. 21	. 17	. 27	0
0	0	. 31	0	0	0
12.79%	10.52%	14.59%	13.33%	12.84%	9.21%
. 21	0	. 21	0	. 22	0
0	0	0	0	0	0
16.12%	13.01%	12.94%	17.69%	15.90%	12.85%
0	0	0	0	0	0
0	0	0	0	0	0
18.85%	....	19.51%	20.0%	15.45%	14.04%
0	....	0	0	0	0
0	....	0	0	0	0
0	0	0	. 20	0	0
0	0	0	. 25	0	0
0	. 16	0	. 19	0	0
0	0	0	. 30	0	0
0	0	0	. 25	. 34	0
0	0	0	0	0	0
. 26	0	0	. 19	. 35	0
0	0	0	. 27	. 43	0
. 17	0	0	. 6	0	0
. 21	0	0	. 14	0	0
0	0	0	. 4	0	0
0	0	0	. 11	0	0
0	0	0	. 21	0	0
0	0	0	. 23	0	0
0	0	. 29	. 17	. 31	0
0	0	. 33	. 25	. 42	0
0	0	0	. 17	0	0
0	0	0	0	0	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Rhodora canadensis L. N. America.	Rhus Toxicodendron L. N. America.
		Days.	Days.
Control	Began growth in	. 24	. 26
	Buds fully open in	. 41	. 34
Etherized 48 hours	Began growth in	. 8	* 7
	Buds fully open in	. 18	. 34
Etherized 48 + 48 hours	Began growth in	* 4	0
	Buds fully open in	0	0
Dried 1 day	Loss of weight	9.33%	4.23%
	Began growth in	* 13	* 25
	Buds fully open in	* 20	* 29
Dried 2 days	Loss of weight	12.92%	6.66%
	Began growth in	. 17	* 24
	Buds fully open in	. 24	* 28
Dried 3 days	Loss of weight	16.86%	9.39%
	Began growth in	* 11	* 15
	Buds fully open in	* 18	* 20
Dried 4 days	Loss of weight	12.30%	11.02%
	Began growth in	. 11	0
	Buds fully open in	. 21	0
Dried 5 days	Loss of weight	17.85%	11.30%
	Began growth in	. 11	0
	Buds fully open in	. 20	0
Frozen 8 days	Began growth in	* 16	* 23
	Buds fully open in	* 25	0
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	* 20	* 20
	Buds fully open in	* 25	* 38
In dark chamber 14 days	Began growth in	* 19	* 23
	Buds fully open in	* 26	* 38
Frozen 8 days; etherized 48 hours	Began growth in	* 10	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	0	0
	Buds fully open in	0	0
Dark chamber 8 days; etherized 48 hours	Began growth in	* 19	0
	Buds fully open in	* 24	0
Dark chamber 8 days; etherized 72 hours	Began growth in	* 15	0
	Buds fully open in	* 20	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Salix pentandra L. Europe & Asia.	Staphylea pinnata L. S. & E. Europe.	Tamarix gallica L. Europe, Asia & Africa.	Tilia alba Ait. N. America.	Tilia grandifolia Ehr. Europe.	Tilia parvifolia Ehr. Europe.
Days.	Days.	Days.	Days.	Days.	Days.
. 9	0	0	. 24	. 21	. 31
. 11	0	0	0	. 28	0
* 8	0	. 8	. 20	. 21	. 21
* 12	0	. 19	0	0	0
* 4	. 19	. 27	0	0	. 17
0	. 14	0	0	0	0
2.51%	10.51%	4.16%	7.48%	8.0%	7.0%
* 16	0	. 18	. 23	. 15	0
* 24	0	. 32	0	. 23	0
8.67%	11.81%	7.81%	10.65%	9.52%	9.57%
* 25	. 14	0	. 16	0	0
. 31	. 14	0	0	0	0
9.34%	17.44%	9.78%	16.12%	14.78%	11.90%
* 14	. 11	0	. 16	0	0
. 20	* 23	0	0	0	0
11.76%	21.17%	11.11%	18.44%	19.20%	14.28%
. 15	. 10	0	. 15	0	0
. 19	* 22	0	0	0	0
11.42%	22.04%	14.58%	23.01%	21.25%	18.88%
* 12	. 15	0	. 14	0	0
* 20	0	0	0	0	0
. 10	. 17	. 17	. 26	0	. 23
. 16	0	. 22	0	0	0
0	0	* 17	0	0	0
0	0	. 30	0	0	0
* 8	. 25	. 20	. 26	. 22	. 21
* 17	0	. 25	0	. 33	0
. 20	0	. 16	. 23	. 23	. 32
. 23	0	. 23	0	0	0
* 2	0	* 7	0	0	0
* 7	0	* 22	0	0	0
* 2	0	* 7	0	0	. 8
* 8	0	* 20	0	0	. 24
* 10	0	. 14	. 25	0	0
* 21	0	. 9	0	0	0
* 6	* 19	. 33	. 18	. 32	. 18
0	0	* 39	0	0	0
* 5	0	0	. 23	0	0
0	0	0	0	0	0

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

TREATMENT.		Ulmus effusa L. Centl. & N. Europe.	Ulmus montana With. Europe & Asia.
		Days.	Days.
Control	Began growth in	* 9	. 16
	Buds fully open in	* 12	. 21
Etherized 48 hours	Began growth in	* 8	....
	Buds fully open in	* 19	....
Etherized 48 + 48 hours	Began growth in	0	....
	Buds fully open in	0	....
Dried 1 day	Loss of weight	6.14%	3.80%
	Began growth in	. 5	. 25
	Buds fully open in	. 5	. 30
Dried 2 days	Loss of weight	8.96%	9.33%
	Began growth in	0	. 27
	Buds fully open in	0	. 31
Dried 3 days	Loss of weight	11.20%	10.04%
	Began growth in	0	. 16
	Buds fully open in	0	. 24
Dried 4 days	Loss of weight	14.49%	19.56%
	Began growth in	0	0
	Buds fully open in	0	0
Dried 5 days	Loss of weight	....	20.80%
	Began growth in	....	0
	Buds fully open in	....	0
Frozen 8 days	Began growth in	. 10	. 21
	Buds fully open in	0	. 28
Frozen 14 days	Began growth in	0	0
	Buds fully open in	0	0
In dark chamber 8 days	Began growth in	. 7	. 16
	Buds fully open in	0	. 23
In dark chamber 14 days	Began growth in	. 7	. 17
	Buds fully open in	0	. 23
Frozen 8 days; etherized 48 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; etherized 72 hours	Began growth in	0	0
	Buds fully open in	0	0
Frozen 8 days; in dark chamber 5 days	Began growth in	0	. 22
	Buds fully open in	0	. 27
Dark chamber 8 days; etherized 48 hours	Began growth in	0	. 13
	Buds fully open in	0	. 21
Dark chamber 8 days; etherized 72 hours	Began growth in	0	. 12
	Buds fully open in	0	. 20

TABLE IX. (*Continued.*)

Treated from December 8 to 23, 1905.

. = Leafbud. * = Flowerbud. 0 = No growth.

Vitis riparia Michx. N. America.	Zanthoxylum fraxineum Willd. N. America.
Days.	Days.
0	* 10
0	* 16
0	* 6
0	* 9
0	* 8
0	* 9
4.76%	8.84%
* 18	* 18
* 26	* 19
5.44%	9.77%
* 18	* 17
* 27	* 18
13.78%	12.39%
* 26	* 16
* 32	* 17
10.90%	15.44%
* 15	* 15
* 82	* 16
10.01%	14.85%
* 14	* 18
* 31	* 14
* 12	* 18
0	* 16
* 18	* 16
* 22	* 28
* 30	* 4
0	* 16
0	* 4
0	0
* 10	* 5
0	* 11
* 11	* 5
* 21	* 12
* 12	* 9
0	* 14
* 18	* 2
* 24	0
* 18	* 1
* 24	0

In Table IX, 70 species were treated and 62 of the number grew. The following 8 made no growth:

Carya aquatica Nutt., North Amer.
Carya porcina Nutt., North Amer.
Juglans regia L., Europe and Asia.
Liriodendron tulipifera L., North Amer.
Prunus Persica Stokes, Asia.
Quercus alba L., North Amer.
Quercus coccinea Wang., North Amer.
Rhododendron ponticum, var. *Cunninghami* L., Southern Europe and Asia Minor.

A summary of the 70 species tested, in the table below, affords some striking comparisons of results secured from the 16 different treatments.

TABLE X.

Summary of Table IX. Seventy species; treated December 17-24, 1905.

TREATMENT.	Average length of time required for beginning growth.	Average length of time required for buds to open fully.	Percentage that grew.	Percentage that opened their buds fully.
	Days.	Days.		
1 Control	**21.5**	28.1	58.5	44.2
2 Etherized 48 hours	**13.1**	**20.3**	**62.8**	**50.0**
3 Etherized 48 + 48 hours	12.7	18.3	47.1	35.7
4 Dried 1 day	20.7	26.2	52.8	45.7
5 Dried 2 days	20.7	25.5	51.4	32.8
6 Dried 3 days	18.0	22.9	47.1	34.2
7 Dried 4 days	19.0	24.4	37.1	28.5
8 Dried 5 days	13.3	18.7	35.7	32.8
9 Frozen 8 days	18.3	23.8	47.1	22.8
10 Frozen 14 days	16.4	23.8	14.2	11.4
11 Dark chamber 8 days	22.8	29.1	55.4	34.2
12 Dark chamber 14 days	23.9	29.2	58.5	32.8
13 Frozen 8 days; etherized 48 hours	11.5	15.5	31.4	15.7
14 Frozen 8 days; etherized 72 hours	**9.9**	16.4	30.0	21.4
15 Frozen 8 days; dark chamber 5 days	17.5	25.0	21.1	20.0
16 Dark chamber 8 days; etherized 48 hours	20.5	26.5	**65.7**	38.5
17 Dark chamber 8 days; etherized 72 hours	18.2	25.8	48.5	35.7

Freezing for 8 days, followed by etherizing for 72 hours caused the quickest average growth, 9.9 days, a gain of 11.6 days over the control.

Severe drying (for 5 days) was as effective as etherizing for 48 hours.

Freezing for 8 days produced a quicker growth than drying for one or two days.

The highest percentage of growth followed the use of the dark-chamber for 8 days, then etherizing for 48 hours, a gain of 7.2 per cent over the control.

The growth was slowest following the use of the dark-chamber alone, loss of one to two days.

Results from drying are interesting. The longer they were dried the smaller the percentage that grew; and, with one exception, the longer they were dried the quicker they grew.

All things considered, etherizing for 48 hours gave the best results.

The value of the methods of treatment for forcing in the order of their worth runs as follows: First, ether (time 12.9 days); second, freezing (time 17.3 days); third, drying (time 18.4 days); and fourth, dark-chamber (time 23.3 days).

The following summary of growth by periods is similar in arrangement and for the same purpose as those given for the other main experiments. Taken in connection with Table X, which is a summary of this last and most important experiment, the following review will prove very interesting and instructive:

TABLE XI.

Summary of Tables IX and X, showing the extent of growth at the end of 1 wk., 2 wks., 3 wks., and, after 3 weeks.

TREATMENT.	Percentage that began growth in				Percentage that opened their buds fully in			
	1 week.	2 weeks.	3 weeks.	More than 3 weeks.	1 week.	2 weeks.	3 weeks.	More than 3 weeks.
Control	0	24.39	26.83	48.78	0	9.68	16.12	74.17
Etherized 48 hours	24.99	40.90	22.72	11.36	2.86	22.86	28.57	45.71
Etherized 48 + 48 hours	30.30	39.39	18.18	12.12	12.0	16.0	48.00	24.00
Dried 1 day	5.26	23.68	34.20	36.83	3.03	3.03	30.30	63.63
Dried 2 days	2.78	24.99	36.10	36.10	0	4.35	39.12	56.51
Dried 3 days	0	37.14	45.71	17.14	0	0	40.00	60.00
Dried 4 days	4.00	32.0	36.00	28.00	0	10.00	35.00	55.00
Dried 5 days	0	68.00	28.00	4.00	0	9.09	40.91	49.99
Frozen 3 days	3.70	33.30	29.62	33.33	0	5.88	35.29	58.82
Frozen 14 days	0	9.09	90.91	0	0	12.50	12.50	75.00
In dark chamber 3 days	7.50	2.50	40.00	50.00	0	4.00	8.00	88.00
In dark chamber 14 days	4.76	2.38	35.71	57.12	0	4.00	4.00	92.00
Frozen 3 days; etherized 48 hours	36.36	36.36	18.18	9.09	9.09	36.36	36.36	18.18
Frozen 3 days; etherized 72 hours	38.09	47.61	4.76	9.52	0	52.23	26.11	19.99
Frozen 3 days; dark chamber 5 days	0	50.00	15.00	35.00	0	13.33	26.66	59.99
In dark chamber 3 days; etherized 48 hours	4.35	13.04	47.91	34.77	0	0	33.33	66.66
In dark chamber 3 days; etherized 72 hours	6.25	18.75	46.87	28.12	0	0	33.33	66.66

Those frozen 8 days and then etherized 72 hours show the largest percentage beginning to grow inside of 7 days—38 per cent. Reference to Table X shows this to have been the treatment that caused growth in the shortest average length of time. A further analysis of the results of this treatment reveals the fact that not only did a relatively large number of the species start into growth within the first few days, but the growth continued until the buds were fully open. With one exception, a smaller number remained unopened after three weeks than followed any other treatment. In other words, after 8 days of freezing and 72 hours etherization, four-fifths of the buds were open inside of 22 days, while only one-fourth of the controls were out. Were it necessary, many other comparisons might be made, showing in detail the effects of the different treatments, particularly the results following the use of the ether or freezing alone and in combination.

5. *Miscellaneous Forcing Experiments.*

Time of treatment from January 13 to January 24, 1906.

A few species were found to force with much difficulty or not at all. A list of these were given some special treatments consisting of ether acting for long periods, injecting with 2 per cent sugar solution, and also with distilled water, under pressure of two atmospheres, and by drying. The results follow:

Aesculus flava: etherized for 96 hours, no growth;
etherized for 72+72 hours, began growth in 30 days; leaves fully open in 35 days;
sugar solution, infiltrated for 2 days, no growth;
water, infiltrated for 1 day, grew in 27 days, but leaves never opened;
dried 1 day, grew in 23 days, but leaves did not open;
dried 2 days, grew in 24 days, but leaves did not open;
dried 4 days, grew in 22 days, leaves opened after 30 days;
dried 5 days, grew in 21 days, leaves opened after 30 days;
dried 6 and 7 days, no growth;
dried 8 days, grew in 22 days, leaves open in 34 days;
control, began to grow in 38 days, but leaves did not open.

Alnus viridis: no growth from etherizing 96 and 72+72 hours, or from injections;
dried 1 day, grew in 20 days, leaves open in 28 days;
dried 2 days, no growth;
dried 3 days, grew in 36 days, leaves open in 46 days;
control, no growth.

Carya aquatica and *C. porcina*: no growth from any of the treatments.

Crataegus macracantha: from etherizing no growth resulted; sugar solution injected, grew in 10 days, leaves open in 28 days;
water injected, grew in 11 days, leaves open in 26 days;
drying, up to 4 days, caused no growth;
control, began to grow in 21 days, but leaves did not open.

Fagus sylvatica: made no growth from any of the treatments but the control grew slightly after 38 days.

Fraxinus excelsior: sugar solution, grew in 23 days; leaves open in 28 days;
water injected, grew in 27 days, leaves open in 35 days;
dried 4 days, slight growth;
control, no growth.

Fraxinus Ornus: a slight growth in 27 days from those that were dried 4 days; no growth from any of the other treatments;
control, no growth.

Juglans regia and *Liriodendron tulipifera*: no growth whatever.

Maclura tinctora: only treated with ether, no growth.
control grew in 6 days, leaves open in 11 days.

Quercus alba and *Q. coccinea*: received all the treatments but made absolutely no growth;
control, no growth.

Quercus pedunculata: etherizing, no growth;
sugar solution, slight growth in flower buds in 9 days, but never opened;

Quercus pedunculata: water injected, slight growth in flower buds, did not open;
dried 1 day, leaf buds grew slightly in 8 days, never opened;
dried 2 days, leaf buds grew slightly in 7 days, but never opened;
dried 3 days, leaf buds grew slightly in 6 days, but did not open;
dried 4 days, leaf buds grew slightly in 12 days, never opened;
dried 5 days, no growth;
control, grew in 19 days, leaves open in 29 days.

Quercus rubra: etherized, no growth;
sugar solution, grew in 9 days, but did not open;
water injected, grew in 8 days, opened in 12 days;
dried 1 day, grew in 4 days, opened in 9 days;
dried 2 days, grew in 3 days, opened in 11 days;
dried 3 and 4 days, no growth;
control, grew in 19 days, and opened in 23 days.

None of the fourteen species made any growth where etherized for 96 hours and only one, *Aesculus flava*, grew from the 72+72 hours treatment. It appears that at this date, with size of dose used and at the given temperature, the limit of endurance to ether is somewhere between *three and four days* continuous exposure, or between *48+48 and 72+72 hours* of exposing alternately to air and to ether. However, care must be exercised in making comparisons between effects in January and those secured in December. Little was done toward trying to force easily reacting plants in January or later, but it was distinctly observed that the difficult species to force were killed in January and February much quicker than in November and December. In January and February there was far more sunlight and it was much more intense than in the two preceding months and of course the mid-day temperature of the greenhouse was often abnormally high for a short time. The consequent increase in transpiration might account for the quicker death of the twigs, as those having no treatment died as quickly as those that had. This may also serve as an explanation why ether is seemingly more active the higher the temperature is when treated, for then there is a sort of two-fold action—a drying process (loss of water by excessive transpiration), and the action of the ether, whatever that may be. On page 70 the data show that the severest treatment out of many was freezing followed by etherization; and freezing is shown by Mez, Molisch and others to not only remove water from the cells but to force it entirely out of the plant. These two conditions—transpiration and freezing—then, are analogous in so far as both deprive the plant of moisture.

When the sugar solution was used four species grew: *Crataegus macracantha, Fraxinus excelsior, Quercus pedunculata,* and *Q. rubra.*

From the pure water injected five kinds grew: *Aesculus flava, Crataegus macracantha, Fraxinus excelsior, Quercus pedunculata,* and *Q. rubra.*

From drying five species grew: *Aesculus flava, Alnus viridis, Fraxinus excelsior, F. Ornus, Quercus pedunculata* and *Q. rubra.*

Six species made no growth at all, naturally or from any of the treatments: *Carya aquatica, C. porcina, Juglans regia, Liriodendron tulipifera, Quercus alba,* and *Q. coccinea.*

On January 19, 1906, the following four species were treated:

Amorpha fruticosa: etherized 24 hours, no growth;
control, no growth.

Cornus Mas: etherized 24 hours, grew in 9 days; leaves open in 12 days;
control, grew in 1 day, flowers open in 2 days; no leaves.

Fagus sylvatica: no growth from the control or the etherized specimens.

Forsythia suspensa: etherized 24 hours, grew in 7 days; leaves open in 7 days;
control, flower buds grew in 2 days, open in 6 days; leaf buds grew in 10 days; open in 12 days.

Here, as was the case when treated in November, *Cornus Mas* made no flower growth when ether was used.

On January 29th aand 30th, 1906, ten species were given the following treatments: Chloroform bath, that is, twigs were placed in a glass tube and shaken up with strong chloroform for a few minutes; chloroform gas (25 grams per 100 liters of space); making a smooth longitudinal slit with a razor through all the bud scales and into the center of the buds; and a well lighted moist chamber made by inverting a large glass jar over the plants in the greenhouse.

The following grew after treatment with the chloroform bath: *Alnus viridis* and *Liriodendron* half opened their buds in two days but grew no farther; this was repeated with half strength with the same results. None grew after treatment with the chloroform gas for forty-four hours.

Cutting the buds resulted as follows: *Aesculus flava* grew in thirteen days, leaves opened after twenty-two days; *Alnus viridis,* both leaves and flowers grew in sixteen days; open after twenty-three days; *Fagus sylvatica* began to grow in twenty-nine days; leaves opened fully after fifty-five days. *Fraxinus Ornus* made a noticeable growth in forty-five days but buds did not open.

Following the moist chamber treatment *Alnus viridis* grew in thirty days but did not open; *Fagus sylvatica* grew in thirty-two days but did not open; *Prunus Persica* grew in four days, opening its flowers in nine days; *Rhododendron ponticum,* var. *Cunninghami* grew in thirty days; buds opened in thirty-eight days.

With the control there was a slight growth in *Aesculus flava* in thirty-one days; good growth in *Amorpha fruticosa* in twenty days; buds open in thirty-two days; and a slight growth of *Prunus Persica* although buds did not open. *Juglans regia, Quercus alba,* and *Q. coccinea* did not grow at all.

In this test *Fagus sylvatica* made a good growth, opening its leaves fully (March 25), for the first time. *Prunus Persica* also grew for the first time.

The effects of wounding the buds (slitting with the razor) were apparent on four of the species. This treatment was in the nature of a mechanical assistance to the buds in opening. It was noticeble with the beech buds that they seemed to be under an internal tension as the wounds yawned open as soon as made.

At different times from February 10 to 17, *Fagus sylvatica* was treated by etherizing for sixteen, twenty-three and twenty-four hours and with half the usual quantity of ether for six hours; slitting the buds and carefully removing all of the scales from the buds, but in no case—controls as well—was there any growth beyond a half-opening of the buds.

6. *A Few Special Treatments.*

Early in the winter several isolated experiments were tried with a few species and some interesting results secured. The first of these tests was with *Cornus Mas* and *Forsythia suspensa.* From November 9 to 14, 1905, *Cornus Mas* was treated with the following results:

Etherized 24 hours, first growth in 14 days, leaves fully open in 36 days.

Etherized 48 hours, first growth in 21 days, leaves fully open in 27 days.

Etherized 72 hours, first growth in 8 days, leaves fully open in 15 days.

Etherized 96 hours, first growth in 9 days, leaves fully open in 13 days.

Etherized 120 hours, first growth in 13 days, leaves fully open in 38 days.

Etherized 144 hours, first growth in 9 days, leaves fully open in 17 days.

Control, first growth in 23 days, flowers fully open in 24 days.

The first four made a vigorous growth, while the next two (120 and 144 hours) were very weak. Not a single flower bud in all those etherized showed any signs of growth and with the control, in this case, there was no leaf growth although the plants were kept until they died. One remarkable feature of this test was the long exposure to ether with growth resulting. Two months later, it is highly probable that such treatment would have killed them speedily.

From November 15 to December 3, *Cornus Mas* was desiccated by submerging twigs in alcohol of strength of 85 to 95 per cent, and in a saturated solution of common salt; also dried in a desiccator over concentrated sulphuric acid, and in a warm room for different periods of time. The results follow:

In alcohol 3½ hours, first growth in 9 days; flowers fully open in 16 days;

In alcohol 23 hours or in NaCl 7½ and 23 hours, no growth;

In desiccator 15 hours, grew in 7 days, flowers fully open in 9 days;

Dried 1 day, loss of weight 11.6%, grew in 6 days; flowers open in 7 days;

Dried 2 days, loss of weight 17%, grew in 7 days but did not open;

In alcohol 23 hours or in NaCl 7½ and 23 hours, no growth;

Dried 4 days, loss of weight 27%, no growth;

Dried 5 days, loss of weight 30.40%, no growth;

Dried 6 days, loss of weight 32.03%, grew in 12 days, leaves did not open;

Dried 7 days, loss of weight 30.96%, no growth;

Dried 8 days, loss of weight 37%, no growth;

Control, first growth in 7 days, flowers open in 8 days.

These figures would seem to indicate that *C. Mas* cannot withstand strong desiccation, but in still another trial the results are somewhat different. Here also the twigs were dried in a warm room; dates, November 16 to December 3, 1905.

Dried 1 day, loss of weight 7.89%, grew in 10 days, flowers open in 11 days;

Dried 2 days, loss of weight 14.28%, grew in 6 days, flowers open in 7 days;

Dried 3 days, loss of weight 18.88%, no growth;

Dried 4 days, loss of weight 21.73%, grew in 7 days, flowers open in 8 days;

Dried 5 days, loss of weight 23.68%, grew in 9 days, flowers open in 10 days.

Dried 6 days, loss of weight 27.34%, grew in 10 days but did not open;

Dried 7 days, loss of weight 25.60%, no growth;

Dried 8 days, loss of weight 20.00%, no growth;

Dried 9 days, loss of weight 22.41%, no growth;

Dried 10 days, loss of weight 31.06%, no growth;

Control, first growth in 23 days, flowers open in 24 days.

In this test drying, up to a certain point, usually gave good results in forcing flower growth, but with this species no flowers have been secured following the use of ether. While ether and desiccation produced the same general results, that is, growth, the particular effects of the two on the flower and leaf buds in *C. Mas* are very different: The drying very rarely produced a leaf, while the ether never produced a flower.

Forsythia suspensa was etherized and desiccated with alcohol and salt solution November 16 to 18, 1905, with the following results:

Etherized 24 hours, grew in 2 days, flowers open in 9 days;

Etherized 48 hours, grew in 3 days, flowers open in 10 days;

In alcohol 22 hours, and in NaCl sol. 22 hours, no growth from either;

Control, first growth in 7 days, flowers open in 13 days, but was really not in full bloom until 7 days later, or 22 days from date placed in greenhouse, while those etherized for 24 hours were in gorgeous full bloom in 9 days from date of treatment.

Other tests with *Forsythia* (not given here) gave similar results. It is injured by 48 hours of ether. On account of the ease, quickness and perfection with which the *Forsythia* is forced in early and mid-winter should make it useful in a commercial way.

Aesculus Hippocastanum treated by air drying from November 25 to December 3, 1905, gave these results;

Dried 1 day, loss of weight 3.30%, grew in 18 days, leaves open in 26 days;

Dried 2 days, loss of weight 3%, grew in 16 days, leaves open in 27 days;

Dried 3 days, loss of weight 3.26%, grew in 15 days, leaves open in 27 days;

Dried 4 days, loss of weight 6.63%, grew in 13 days, leaves open in 18 days;

Dried 5 days, loss of weight 8.67%, grew in 12 days, leaves open in 17 days;

Dried 6 days, loss of weight 10.52%, grew in 10 days, leaves open in 16 days;

Dried 7 days, loss of weight 11%, grew in 26 days, leaves open in 31 days;

Dried 8 days, loss of weight 10.48%, grew in 21 days, leaves open in 28 days;

Control, grew in 20 days and opened its leaves in 31 days.

The results are interesting in that up to 6 days the more they were dried the quicker the growth began. *Castanea pumila* similarly treated at the same time made no growth at all.

Castanea vesca made a full growth in 15 to 16 days when dried 5, 6 and 7 days, with loss of weight of from 19 to 23 per cent; the control made a slightly better growth at the end of 21 days. *Gleditschia triacanthos* made no growth when dried up to 9 days, and *Robinia Pseud-acacia* grew very slightly when dried 1 day, loss of weight 6.32%, growth in 20 days; and when dried 7 days—loss of weight 21.79%—grew in 13 days.

EXPERIMENTS WITH POTTED PLANTS.

Of much more interest were the developments from treating a few specimens of *Quercus pedunculata* which had been growing in pots for two years, or from the time they came from the seed. During late autumn and up to the time the experiment began, the pots were kept in a coldframe in the garden where they were slightly protected with board covers, but had absolutely no artificial heat. The weather record (Table XII, pp. 83-4) shows that on the 20th and 21st of October there were freezing temperatures and again on the 12th, 17th, 18th, 19th, and 21st of November the outside temperature was below zero Centigrade. It is highly probable that after once becoming frozen they did not thaw out again as the bed was in the shade and not much influenced by the outside temperature. When removed for treatment on November 25 the soil in the pots was frozen quite hard. For a day the plants were kept in a cool basement room at about 10° C. in order that they might thaw out gradually. Between November 27 and December 9 all were treated with ether and artificial freezing, one plant being used for each treatment. The results follow:

November 28, etherized 24 hours, leaves fully open 30 days.
November 27, etherized 28 hours, leaves fully open 24 days.
December 1, etherized 48+48 hours, leaves fully open 14 days.
December 9, frozen 7 hours, leaves fully open 34 days.
November 27, control, leaves fully open 31 days.

According to the results, growth was accelerated in direct proportion to the increase of the ether, the greatest acceleration being 17 days. Strong freezing actually retarded the growth and it should be added that the plant was so badly injured that it died within a few days after the leaves were out.

The most astonishing feature about this case was that the oaks should have grown at all, especially the control, as similar plants of the same species in the same room made absolutely no signs of growth when kept there all winter without treatment. These plants, however, had always been kept in this greenhouse during the two years of their life, but they still go dormant in autumn and remain so until spring.

The explanation of the behavior of the treated oaks, it is believed, lies in the fact of their having been frozen before treatment and sufficiently so to cause growth. The ether, however, accelerated the growth in very marked degree.

All three of the etherized oaks, together with the control, made a luxuriant leaf growth (the treated ones being somewhat better) forming branches and increasing the length of the main stem. An-

other note-worthy feature of their further behavior was, that after forming from 12 to 20 full grown leaves, all began to show signs of slow growth. All but one were now removed to a cool greenhouse where the day temperature was between 7° and 10° C. and the humidity 80 to 85 per cent. Here they soon ceased to grow entirely and during the first week in March were observed to have developed strong terminal buds. But the specimen remaining in the warm greenhouse exhibited the same phenomenon of forming a terminal bud, although slightly later than the others. This plant was now also removed to the cool room.

The first week in May the control specimen and the one that had been etherized 48 hours began to grow again and a week later the one etherized 48+48 hours also grew. The remaining plant, which had had 24 hours of ether, was nearly two weeks later still, in beginning growth. The first three began to grow at about the same time as some others in pots that had been in the cool greenhouse all winter.

From December 18 to 24 more of the *Quercus pedunculata* in pots were treated as follows:

1. Etherized 72 hours, leaves were fully open after 23 days.
2. Frozen 5 days, leaves were fully open after 67 days.
3. In dark-chamber 20 days, leaves were fully open after 30 days.
4. Control, leaves were fully open after 23 days.

These plants were under the same conditions before treatment as those in the preceding test, that is, in a coldframe in the garden and, of course, had been frozen. Indeed, the last days of November and first week of December were colder than early in November (see Table XII) and hence they had been frozen for about a month, which may account for the slight effects of the treatment. As the data show, none of the treatments hastened the growth at all and the freezing and dark-chamber greatly retarded it, the freezing especially being injurious in this respect.

The first, third and fourth of the above ceased growing and formed resting buds in March but the second had at that time only begun to grow and that very feebly. In fact the growth that did occur came from a sprout which grew out from the base of the plant.

Mediterranean Plants.—Twigs of a number of Mediterranean species were taken from plants kept in a cool plant house and placed in the warm greenhouse November 18, 1905, but were not treated.

They remained in fresh water until all died (some living until March), but there were no signs of growth in any of the species. The following is the list:

Buxus balearica Lam.
Ceratonia Siliqua L.
Citrus vulgaris Risso.
Ficus Carica L.
Laurus nobilis L.
Myrtus communis L.
Nerium oleander L.
Olea europaea L.
Phillyrea latifolia L.
Pistacia vera L.
Prunus Pseudo-Suber L.
Viburnum Tinus L.

TABLE XII.

DAILY TEMPERATURES DURING THE WINTER OF 1905-6.

From the Weather Bureau of the Agricultural Institute of the University of Halle.

PROF. DR. HOLDEFLEISS, *Observer*.

* = Hoar-frost.

Date.	OCTOBER.			NOVEMBER.			DECEMBER.			JANUARY.			FEBRUARY.		
	Temperature Cent.			Temperature Cent.			Temperature Cent.			Temperature Cent.			Temperature Cent.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
1	12.7	6.8	9.0	14.2	6.5	9.0	1.5	—1.0*	0.7	—3.9	—9.7	—5.9	3.1	—0.9*	1.6
2	11.4	7.3	9.0	10.4	2.2	6.0	2.0	—0.4	0.0	—3.5	—8.2	—7.0	4.2	2.2	2.9
3	11.4	6.7	7.8	12.0	6.0	8.4	0.2	—2.2	—1.2	—1.9	—9.0	—5.0	3.5	0.4	1.2
4	11.6	4.5	9.3	12.2	4.7	7.0	—0.6	—2.4*	—0.1	4.5	—5.2	2.2	1.9	—1.2	—0.1
5	13.6	7.2	9.4	11.8	4.2	8.8	0.8	—0.9	0.0	8.8	2.5	5.9	0.4	—1.4	—0.5
6	10.8	6.5	7.6	12.7	5.5	8.4	2.4	—1.1	1.1	7.0	4.3	6.6	0.2	—1.2	—0.9
7	9.6	5.6	6.9	9.9	0.6*	4.9	6.5	1.3	5.1	8.0	3.2	5.0	—0.1	—1.1	—0.6
8	9.5	5.8	7.3	7.3	4.1	6.0	11.4	6.2	10.4	5.3	1.4	3.7	2.8	—0.8	1.2
9	8.2	3.8	6.6	6.7	5.1	5.6	11.2	4.0	5.6	5.5	1.2	3.2	1.2	—1.5	—0.8
10	8.5	5.0	6.3	6.0	3.7	4.0	6.9	1.9	4.8	7.3	3.3	4.4	2.5	—2.4	—0.8
11	9.4	2.6*	6.6	5.6	1.4	2.6	4.8	0.9	2.5	6.2	1.8	3.8	3.6	—1.6	1.0
12	8.6	5.5	7.0	4.8	—0.4*	1.6	3.0	—0.2	1.7	5.0	1.1*	3.5	4.4	—2.1	0.4
13	9.5	4.4	6.4	4.1	1.2	2.9	4.3	0.7	3.2	9.8	3.2	7.3	0.2	—2.5	—1.5
14	7.5	1.7	5.0	3.7	2.0	2.4	7.2	3.9	6.1	8.6	3.1	4.1	0.7	—3.5	—0.6
15	9.0	3.8	5.9	3.5	0.2	1.2	7.1	5.3	6.0	6.8	1.4*	3.4	4.0	—0.5	1.6
16	9.6	1.8	4.5	1.4	—0.2	0.2	6.4	4.3	5.1	8.7	1.4	5.0	5.3	—0.2	1.6
17	9.0	3.4	4.9	2.2	—0.7	—0.0	5.5*	—0.8	0.6	10.1	1.8	3.7	7.5	—1.4	3.0

TABLE XII. (*Continued.*)

DAILY TEMPERATURES DURING THE WINTER OF 1905-6.
From the Weather Bureau of the Agricultural Institute of the University of Halle,
PROF. DR. HOLDEFLEISS, *Observer.*

* = Hoar-frost.

Date.	OCTOBER.			NOVEMBER.			DECEMBER.			JANUARY.			FEBRUARY.		
	Temperature Cent.			Temperature Cent.			Temperature Cent.			Temperature Cent.			Temperature Cent.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
18	7.9	1.6*	3.8	2.1	-2.2*	-0.9	-0.2*	-3.6	-3.2	9.6	1.5	6.6	5.7	2.4	3.9
19	6.9	1.5*	3.2	1.6	-2.3*	-0.4	0.9*	-4.9	-1.8	9.8	1.8	3.5	4.5	2.1	3.0
20	6.0	-1.0*	1.1	2.2	0.4	1.2	2.8	-1.8	1.7	4.0	0.7	1.8	5.7	2.2	3.7
21	7.2	-1.9*	2.8	5.5	-1.1	2.6	4.2	2.0	3.6	4.2	1.3	2.0	5.8	1.6	3.2
22	5.6	1.0	3.1	3.4	1.7*	1.0	6.8	3.7	5.6	1.8	-3.9	-2.4	5.6	0.8	2.2
23	6.1	0.1*	2.7	3.3	0.8*	1.7	6.5	4.3	5.2	-2.1	-5.7	-4.4	6.0	0.6	2.8
24	4.3	0.2	1.2	5.5	1.6	3.3	4.6	2.3	2.6	-1.6	-5.9	-3.1	3.3	-0.1	0.9
25	4.0	-1.2*	1.2	6.3	2.1	3.4	3.0	-0.3	0.5	-1.7	-8.6	-4.5	4.5	-1.0*	2.2
26	5.5	0.4	2.0	8.7	0.9*	6.4	2.0	-0.7	1.4	2.3	-4.4	1.0	6.9	2.0	4.6
27	3.8	-0.6	2.5	11.7	4.4	6.9	5.5	1.2	2.3	6.7	2.0	4.5	9.5	4.4	7.8
28	8.4	2.1	5.2	7.0	2.2	3.5	1.7*	-2.6	-1.2	6.8	4.2	5.1	8.3	3.2	4.8
29	9.0	3.3	6.0	4.5	-0.1*	1.2	5.0	-0.4	3.3	4.9	2.8	4.1	....	....	....
30	12.4	5.3	9.3	0.5	-2.3*	-1.2	5.5	-4.8	-2.5	6.0	3.2	4.1	....	....	....
31	13.0	8.8	9.8	....	....	....	-3.3	-6.3	-4.6	4.4	1.0	1.7	....	....	....
Monthly Sum.	270.0	102.0	173.4	190.8	48.3	108.5	126.8	7.6	64.5	148.2	-12.4	63.4	111.2	-1.5	48.0
Monthly Mean.	8.7	3.3	5.6	6.4	1.6	3.6	4.1	0.2	2.1	4.8	-0.4	2.0	4.0	-0.1	1.7

EXPERIMENTS DURING THE WINTER OF 1906-7.

(Tables XIII, XIV and XV.)

These experiments were carried on in the Horticultural Department of the University of Missouri during the fall of 1906 and the winter of 1907. In these tests three objects were sought:

First, to compare the behavior of plants grown here with similar species grown in central Europe,

Second, to test the effect of time of year—that is, the date when treatment was given, on the number of days required for growth to begin; and,

Third, to find whether dormant plants while being etherized give off more moisture than plants under similar conditions untreated.

Only a short list of species was used as it was desired only to test a few typical forms that had been found to force easily, such as the *Forsythia,* to force with moderate ease, as the *Acer, Platanus* and *Castanea,* and some that grew with great difficulty, like the *Fraxinus* and *Quercus alba.* Unfortunately it was not practicable to secure *Fagus* and *Liriodendron* in sufficient quantity to include them in the experiments.

Only two general treatments were employed—etherizing and air drying in a warm, dry, laboratory room. By omitting many of the combination treatments the number of plants to be handled was sufficiently reduced to make it possible to treat a new set every ten days from late fall until the close of winter. The same methods of treatment were followed in these tests as were employed the previous winter. Also the same quantity of ether was used as before, that is, forty grams per one hundred liters of space.

The treatments began on October 30, 1906, and were repeated every ten days until February 12, 1907, thus covering a period of ninety days. Thirteen species were used. In Table XIII which follows will be seen the results of the treatments in detail, arranged in groups according to date of treatment:

TABLE XIII.

Thirteen species treated on different dates by etherizing and by drying during the fall and winter of 1906-7.

	Control.	Etherized 24 hours.	Etherized 24 + 24 hours.	Etherized 48 hours.	Etherized 48 + 48 hours.	Dried 1 day.	Dried 2 days.	Dried 3 days.	Dried 4 days.	Dried 5 days.	Dried 6 days.	Dried 7 days.	Dried 8 days.	Dried 9 days.	Dried 10 days.
1 Treated between Oct. 30 and Nov. 10, 1906.	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in
	days	days	days	days	days	days	days	days	days	days	days	days	days	days	days
Acer platanoides L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Acer rubrum L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Acer saccharinum Wang.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	11	17	—	—	—	0	0	0	0	0	—	—	—	—	—
Fraxinus viridis Michx.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Gleditschia triacanthos L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Platanus occidentalis L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Quercus alba L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Taxodium distichum Rich.	0	56	—	—	—	0	0	0	0	0	0	0	0	0	0
Thuja occidentalis L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Ulmus americana L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0

TABLE XIII. (*Continued.*)

8

Treated between Nov. 13 and 28, 1906.

Acer platanoides L.	0	0	—	—	—	0	0	0	0	0	0	0	20	28	21
Acer rubrum L.	0	0	—	—	—	0	0	0	0	26	16	0	0	0	0
Acer saccharinum Wang.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	15	10	—	—	—	22	0	23	31	0	—	—	—	—	—
Fraxinus viridis Michx.	48	61	—	—	—	0	55	47	48	43	0	21	44	22	15
Gleditschia triacanthos L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Platanus occidentalis L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Quercus alba L.	0	0	—	—	—	0	0	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Englm.	0	40	—	—	—	44	0	0	0	0	0	0	0	0	0
Taxodium distichum Rich.	37	0	—	—	—	0	0	0	41	0	0	0	0	0	0
Thuja occidentalis L.	43	0	—	—	—	0	0	0	27	0	0	0	0	0	0
Ulmus americana L.	37	44	—	—	—	44	43	0	0	0	0	0	0	0	0

3

Treated between Nov. 24 and Dec. 4, 1906.

Acer platanoides L.	0	—	0	0	10	0	18	0	0	0	0	0	.0	0	0
Acer rubrum L.	0	—	0	0	14	0	0	0	0	0	0	0	0	0	0
Acer saccharinum Wang.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	—	0	0	33	0	0	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	11	10	4	—	—	23	16	21	12	11	—	—	—	—	—
Fraxinus viridis Michx.	0	—	34	17	0	23	26	0	0	38	31	0	36	30	0
Gleditschia triacanthos L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Platanus occidentalis L.	0	—	0	0	0	0	0	0	0	0	0	0	0	28	0
Quercus alba L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Taxodium distichum Rich.	30	—	29	0	0	0	0	0	0	0	0	0	0	0	0
Thuja occidentalis L.	0	—	17	18	0	0	0	0	0	25	0	0	0	0	0
Ulmus americana L.	0	—	13	0	0	0	0	23	0	11	0	0	0	0	0

TABLE XIII. (*Continued.*)

Thirteen species treated on different dates by etherizing and by drying during the fall and winter of 1906-07.

4 Treated between Dec. 5 and 15, 1906.	Control. Growth began in	Etherized 24 hours. Growth began in	Etherized 24 + 24 hours. Growth began in	Etherized 48 hours. Growth began in	Etherized 48 + 48 hours. Growth began in	Dried 1 day. Growth began in	Dried 2 days. Growth began in	Dried 3 days. Growth began in	Dried 4 days. Growth began in	Dried 5 days. Growth began in	Dried 6 days. Growth began in	Dried 7 days. Growth began in	Dried 8 days. Growth began in	Dried 9 days. Growth began in	Dried 10 days. Growth began in
	days	days	days	days	days	days	days	days	days	days	days	days	days	days	days
Acer platanoides L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer rubrum L.	0	—	0	45	0	0	0	0	0	0	0	0	0	0	0
Acer saccharinum Wang.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	—	0	47	29	0	0	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	19	6	12	—	—	14	17	0	9	10	—	—	—	—	—
Fraxinus viridis Michx.	30	—	21	49	15	21	42	0	22	25	0	19	0	13	16
Gleditschia triacanthos L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Platanus occidentalis L.	0	—	63	61	65	46	0	74	0	0	41	0	0	38	0
Quercus alba L.	0	—	0	47	29	0	28	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	0	—	0	0	24	0	52	0	0	0	0	0	0	0	0
Taxodium distichum Rich.	0	—	12	14	13	18	0	0	15	21	0	0	0	0	0
Thuja occidentalis L.	26	—	16	69	0	0	21	68	0	0	0	21	0	0	0
Ulmus americana L.	19	—	0	2	0	48	18	0	19	0	0	0	0	0	0

TABLE XIII. (*Continued.*)

5

Treated between Dec. 15-26, 1906.

Acer platanoides L.	0	—	0	0	0	0	0	0	0	0	0	0	22	18	0
Acer rubrum L.	0	—	0	0	0	0	0	0	0	0	0	0	26	0	0
Acer saccharinum Wang.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	—	0	0	28	0	49	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	13	12	8	—	—	13	11	15	9	10	—	—	—	—	—
Fraxinus viridis Michx.	13	—	17	16	48	33	51	34	26	8	7	23	8	0	0
Gleditschia triacanthos L.	0	—	0	81	0	0	0	0	0	0	0	0	0	0	0
Platanus occidentalis L.	0	—	0	70	50	71	74	55	0	51	47	0	0	25	0
Quercus alba L.	0	—	0	35	19	33	0	33	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	41	—	0	31	31	0	0	0	0	0	0	0	0	0	0
Taxodium distichum Rich.	0	—	6	16	5	0	0	0	0	22	0	0	0	0	0
Thuja occidentalis L.	0	—	13	16	0	0	0	0	0	0	22	20	0	0	0
Ulmus americana L.	20	—	0	0	0	0	28	0	9	0	0	4	0	0	0

6

Treated between Dec. 25, 1906 and Jan. 4, 1907.

Acer platanoides L.	0	—	0	0	0	0	0	57	0	52	0	0	0	0	0
Acer rubrum L.	0	—	40	6	7	0	0	0	34	22	0	0	0	0	0
Acer saccharinum Wang.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	—	0	0	23	0	0	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	13	10	9	—	—	0	13	10	17	16	—	—	—	—	—
Fraxinus viridis Michx.	43	—	19	27	0	26	23	24	23	8	21	10	14	0	0
Gleditschia triacanthos L.	15	—	5	49	0	0	64	0	0	0	0	0	0	0	0
Platanus occidentalis L.	64	—	0	0	51	45	61	0	0	0	56	44	0	0	0
Quercus alba L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	41	—	0	0	0	0	44	24	0	0	0	0	0	0	0
Taxodium distichum Rich.	20	—	10	22	21	21	22	14	0	19	14	17	0	0	0
Thuja occidentalis L.	22	—	17	1	16	19	20	19	16	24	0	20	0	42	0
Ulmus americana L.	8	—	0	0	0	2	6	5	4	12	0	0	0	0	0

TABLE XIII. (*Continued.*)

Thirteen species treated on different dates by etherizing and by drying during the fall and winter of 1906-07.

7 Treated between Jan. 5-21, 1907.	Control.	Etherized 24 hours.	Etherized 24 + 24 hours.	Etherized 48 hours.	Etherized 48 + 48 hours.	Dried 1 day.	Dried 2 days.	Dried 3 days.	Dried 4 days.	Dried 5 days.	Dried 6 days.	Dried 7 days.	Dried 8 days.	Dried 9 days.	Dried 10 days.
	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in	Growth began in
	days	days	days	days	days	days	days	days	days	days	days	days	days	days	days
Acer platanoides L.	53	—	29	47	14	52	51	0	51	48	0	0	0	0	0
Acer rubrum L.	11	—	27	25	26	0	49	13	54	0	0	0	0	0	0
Acer saccharinum Wang.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	—	0	33	21	43	0	41	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	11	15	8	—	—	12	0	0	0	8	—	—	—	—	—
Fraxinus viridis Michx.	32	—	37	38	0	31	42	37	0	13	0	13	30	0	0
Gleditschia triacanthos L.	0	—	9	7	12	43	0	0	0	0	0	0	0	0	0
Platanus occidentalis L.	53	—	43	33	26	45	45	46	49	30	0	0	0	0	0
Quercus alba L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	32	—	0	25	0	43	0	32	0	0	0	0	0	0	0
Taxodium distichum Rich.	16	—	8	9	0	0	14	13	0	8	0	0	0	0	0
Thuja occidentalis L.	0	—	13	0	10	52	0	37	0	41	0	0	0	0	0
Ulmus americana L.	10	—	17	28	0	0	0	0	0	0	0	6	0	0	0

TABLE XIII. (Continued.)

8

Treated between Jan. 21 and Feb. 2, 1907.

Acer platanoides L.	24	—	13	17	13	18	28	30	26	25	0	19	0	0	0
Acer rubrum L.	24	—	0	0	24	34	0	0	0	0	0	0	0	0	0
Acer saccharinum Wang.	0	—	0	17	13	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	35	—	0	0	20	0	0	0	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	11	10	8	—	—	10	9	8	7	6	—	—	—	—	—
Fraxinus viridis Michx.	21	—	0	0	0	13	35	0	0	0	24	0	0	0	0
Gleditschia triacanthos L.	0	—	27	23	5	34	0	36	0	0	0	0	0	0	0
Platanus occidentalis L.	35	—	0	0	15	34	0	34	33	30	0	19	16	0	0
Quercus alba L.	0	—	36	0	22	0	26	26	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	30	—	21	26	20	0	35	21	0	19	0	0	0	0	0
Taxodium distichum Rich.	4	—	8	33	13	33	0	8	7	0	0	0	0	0	0
Thuja occidentalis L.	21	—	21	17	13	23	24	21	0	0	0	0	0	0	0
Ulmus americana L.	4	—	17	0	0	7	9	8	7	9	0	0	0	0	0

9

Treated between Feb. 2-12, 1907.

Acer platanoides L.	0	—	0	16	8	0	0	0	14	0	0	0	17	0	13
Acer rubrum L.	7	—	4	7	3	6	14	4	0	4	0	11	0	0	0
Acer saccharinum Wang.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanea sativa, var. americana Watson	0	—	20	0	17	0	0	18	0	0	0	0	0	0	0
Forsythia suspensa Vahl.	9	6	6	—	—	6	5	9	5	7	—	—	—	—	—
Fraxinus viridis Michx.	7	—	20	10	17	0	23	0	10	0	17	0	15	0	0
Gleditschia triacanthos L.	6	—	4	5	0	0	0	18	0	20	0	0	0	0	0
Platanus occidentalis L.	0	—	22	0	19	0	0	0	0	0	15	18	17	0	0
Quercus alba L.	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus Muehlenbergii Engelm.	0	—	22	19	8	26	25	18	14	0	0	0	0	0	0
Taxodium distichum Rich.	14	—	13	0	6	0	0	11	23	18	17	18	0	0	0
Thuja occidentalis L.	16	—	11	12	8	26	16	13	19	18	15	0	0	0	0
Ulmus americana L.	7	—	0	0	1	6	5	0	5	0	0	0	0	0	0

In the first test only two species grew, the golden bell and the bald cypress.

In the second treatment it is surprising to note the behavior of the green ash which grew from both etherizing and drying and also where not treated. This particular species was not included in any of the tests conducted the year before in Germany, but the white ash, *Fraxinus americana* was, and the two species are very similar in every respect.

The *Fraxinus viridis* grew in every one of the nine tests. In the second experiment the sugar maple, chestnut, honey locust, sycamore and white oak made no growth.

In the third trial the honey locust and white oak still did not grow, and, from some cause, the chinquapin oak failed to start, although it grew in a previous test.

In the fourth test—December 5-15, the *Quercus alba* grew from two of the strong ether treatments and also in one instance from slight drying. It also grew in the next test ten days later, from four of the treatments. The year before, the same species grown in Germany, could not be made to grow from any treatment until almost spring.

In tests six, seven and nine the *Quercus alba* made no growth, but it grew from four treatments in the eighth experiment. In no case, however, did the control specimens make any growth. The entire results of all the tests are summarized in Table XIV.

TABLE XIV. (Summary of Table XIII.)

Record of 13 species treated at different times by etherizing and drying, showing the average number of days required for growth to begin and the percentage that grew from each treatment.

TREATMENT.	1. Treated between Oct. 30 & Nov. 10, 1906.		2. Treated between Nov. 13 & 23, 1906.		3. Treated between Nov. 24 & Dec. 4, 1906.		4. Treated between Dec. 5 & 15, 1906.		5. Treated between Dec. 15 & 25, 1906.		6. Treated between Dec. 25, '06 & Jan. 4, '07.	
	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew
Control	11.	7.69	36.	38.45	21.5	15.38	23.5	30.76	21.7	30.76	25.7	61.52
Etherized 24 hours.	36.5	15.38	38.7	30.76	10.	7.69	6.	7.69	12.	7.69	10.	7.69
Etherized 24 + 24 hours.	....	....	....	....	19.4	38.45	20.8	38.45	11.	30.76	16.6	46.14
Etherized 48 hours	....	....	....	....	17.5	16.66	41.7	68.64	30.7	58.31	21.2	41.65
Etherized 48 + 48 hours.	....	....	....	....	19.	24.99	29.1	49.98	30.1	49.98	23.6	41.65
Dried 1 day	0	0	36.6	23.07	23.	15.38	29.4	38.45	38.7	30.76	22.6	38.45
Dried 2 days	0	0	49	15.38	20.	23.07	28.8	46.14	42.6	38.45	31.6	61.52
Dried 3 days	0	0	35	15.38	22.	15.38	71.	15.38	35.5	30.76	21.8	53.83
Dried 4 days	0	0	38.7	23.07	12.	7.69	16.2	30.76	14.6	23.07	18.8	38.45
Dried 5 days	0	0	34.5	15.38	21.2	30.76	18.6	23.07	22.7	30.76	21.8	53.83
Dried 6 days	0	0	16	7.69	31.	8.33	41.	8.33	25.3	24.99	30.3	24.99
Dried 7 days	0	0	21	7.69	0	0	20.	16.66	15.6	24.99	22.7	33.32
Dried 8 days	0	0	36.6	15.38	36.	8.33	0	0	18.6	24.99	14.	8.33
Dried 9 days	0	0	25	15.38	29.	16.66	25.5	16.66	21.5	16.66	42.	8.33
Dried 10 days	0	0	18	15.38	0	0	16.	8.33	0	0	0	0

TABLE XIV. (Summary of Table XIII.) (*Continued.*)

Record of 13 species treated at different times by etherizing and drying, showing the average number of days required for growth to begin and the percentage that grew from each treatment.

TREATMENT.	7. Treated between Jan. 5 & 21, 1907.		8. Treated between Jan. 21 & Feb. 21, 1907.		9. Treated between Feb. 2 & 12, 1907.	
	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew	Av. No. Days for growth to begin	Percentage that grew
Control	27.2	61.52	19.9	76.90	9.4	53.83
Etherized 24 hours	15.	7.69	10.	7.69	6.	7.69
Etherized 24 + 24 hours	21.2	69.21	18.8	61.52	13.4	69.21
Etherized 48 hours	27.2	75.07	22.	49.98	11.5	49.98
Etherized 48 + 48 hours	13.1	49.98	15.8	83.30	9.6	75.07
Dried 1 day	41.8	61.52	23.4	69.21	14.	38.45
Dried 2 days	40.2	38.45	23.7	53.83	14.6	46.14
Dried 3 days	31.2	53.83	21.1	69.21	13.	53.83
Dried 4 days	51.8	23.07	16.	38.45	12.8	53.83
Dried 5 days	29.6	46.14	17.8	38.45	13.4	38.45
Dried 6 days	0	0	24.	8.33	16.	33.32
Dried 7 days	9.5	16.66	19.	16.66	15.6	24.99
Dried 8 days	30.	8.33	16.	8.33	16.3	24.99
Dried 9 days	0	0	0	0	0	0
Dried 10 days	0	0	0	0	13.	8.33

The summary just given is disappointing in that it shows little uniformity in the results of the treatments. One point which is decisively brought out however, is the apparent quickening of growth caused by many of the treatments, beginning with the third period, growing longer again with the fourth period and remaining up until the eighth period, when the average number of days required for growth to begin suddenly declined and continued to decline through the ninth period.

The lack of uniformity of results in this table in part, may be attributed to the fact that the number of species treated was so small. A close scrutiny of the table, however, is interesting in that it shows, on the whole, that the tendency or, ability to grow, rises and falls during the course of the winter. This feature of the results is shown more clearly in the following table, which shows the average number of days required for growth to begin under each treatment, regardless of the dates on which treatments were given and in similar manner the percentages that grew are given:

TABLE XV.

Treatment.	Av. No. days for growth to begin	Percentage that grew.
Control	21.6	41.87
Etherized 24 hours	16.0	11.09
Etherized 24 + 24 hours	17.3	50.53
Etherized 48 hours	17.3	50.3
Etherized 48 + 48 hours	20.7	53.57
Dried 1 day	23.6	41.91
Dried 2 days	31.3	40.37
Dried 3 days	31.3	33.90
Dried 4 days	22.3	29.79
Dried 5 days	22.4	34.61
Dried 6 days	26.2	16.56
Dried 7 days	17.6	20.13
Dried 8 days	23.9	14.09
Dried 9 days	23.6	15.13
Dried 10 days	15.6	10.64

Two tests were made with dormant twigs to find if they would give off more moisture when etherized—that is, while exposed to the ether vapor—than when merely enclosed in a glass jar but not treated. During the course of the experiments the previous year it was noticed that there seemd to be more moisture in the etherized jars than in the controls.

Two methods were employed in making the tests: In the one case hygrometers were placed in the jars and readings taken at different times covering a period of a few days; in the other case weighed quantities of calcium chloride were placed in the jars and afterwards reweighed to show the amount of moisture absorbed.

Hygrometer Test.—Two bundles of dormant twigs were placed in large glass jars and a hygrometer and a self-registering max. and min. thermometer so arranged in each that they could be easily read from the outside. In one jar was poured thirteen grams of ether (which was at the rate of forty grams per one hundred liters of space) and the other left untreated for comparison. Both jars were kept tightly closed during the eight days the experiment lasted. The experiment began early in the afternoon of January 24, 1907, and ended on February 1, following. The hygrometric reading showed fifty per cent of moisture in the jars before the twigs were put in. The temperature was 20° C. Following is an account of the readings in both jars:

TABLE XVI.

Etherized and both jars closed at 2 o'clock p. m., January 24, 1907.

OBSERVATIONS.	Humidity.		Temperature.	
	Control.	Etherized.	Control.	Etherized.
	Per cent.	Per cent.	Deg. C.	Deg. C.
Original Humidity and Temperature ...	50	50	20	20
After 8 hours (Jan. 24, 5 p. m.)	80	80	21.1	21.1
After 17¾ hours (Jan. 25, 7:45 a. m.) .	85	87	17.8	17.8
After 29¾ hours (Jan. 26, 7:45 p. m.)	82.5	85	21.1	21.1
After 34 hours (Jan. 28, 12 m.)	81	82.5	22.7	22.7
After 87 hours (Jan. 28, 3 p. m.)	81	82.5	22.7	22.7
After 9 days (Feb. 1)	85	85	18.9	18.9

Calcium Chloride Test.—Bundles of dormant twigs as nearly alike as possible were placed in two large glass jars. In each were also a thermometer, hygrometer, and 100 grams of calcium chloride. One jar was treated with 10½ grams of ether, this being at the rate of 40 grams per 100 liters of space. The experiment lasted three days—from February 9th to 12th inclusive. The same self-registering maximum and minimum thermometers employed before were again used. The results are shown in the following table:

TABLE XVII.

Etherized and both jars closed at 12 o'clock noon February 9, 1907.

OBSERVATIONS.	Humidity.		Temperature.	
	Control.	Etherized.	Control.	Etherized.
	Per cent.	Per cent.	Deg. C.	Deg. C.
Original Humidity and Temperature ...	50	50	20.5	20.5
After 4½ hours (Feb. 9, 4:30 p. m.) .	74	79	20.5	21.1
After 27 hours (Feb. 10, 2:30 p. m.) ..	80	82.5	16.7	17.8
After 46½ hours (Feb. 11, 10 a. m.) ..	75	82.5	20.5	21.1
After 57½ hours (Feb. 11, 9 p. m.) ...	75	80	17.8	18.3
	Grams.	Grams.		
Original weight of Calcium Chloride ...	100	100		
Weight after 3 days (Feb. 12)	125	135		
Increase in weight	25	35		

In Table XVI it is observed that the amount of moisture increased rapidly in both the etherized and the control jars during the first three hours after treatment—the increase in each case being 30 per cent. At the next observation, however, it is noticed that, while the moisture continued to increase, the etherized jar showed the highest percentages. This continued to be true up to the end of 37 hours, after which time both jars gradually declined until the difference in their reading was only one and one-half per cent. The temperature of the room fluctuated considerably.

The ether evidently caused a decided acceleration in the transpiration—the maximum activity occurring at the end of about 17 hours after treatment. It will further be noticed that at this observation the temperature reached its lowest point, a condition which no doubt helped to increase the humidity.

A final reading was taken on February 1st, more than a week afterward, at a time when the temperature was low, both jars showing the same amount of moisture—85 per cent. The cause of the decline in both jars was no doubt due to the fact that the vapor condensed on the glass and flowed to the bottom. After this, although the temperature was low at the last reading, the percentages of the etherized and control jars were the same, the water on the sides and bottoms of the vessels in both cases tending to equalize the humidity as measured by the hygrometers.

In previous temperatures, where the room temperature fluctuated but little, it was noticed that the vapor usually condensed on the sides of the jars in about 20 hours after treatment.

In Table XVII are noted the results of the second attempt, to find whether ether causes dormant twigs to give off more moisture than similar twigs untreated. At the first observation, 4½ hours after treatment, the etherized jar contained five per cent more moisture than the control. The percentage of moisture continued to be higher in the etherized than in the control up to the end of 57½ hours, when the difference was again five per cent. The difference here was twice as great as in the previous trial.

Table XVII also shows the approximate total amount of humidity (in the form of both vapor and water) present in the jars, the calcium chloride having absorbed the moisture. The data showed the presence of 10 grams more water in the etherized jar than in the other. Reference to the table, however, shows that at the end of the experiment the atmosphere in the jars was still quite humid but the etherized one was several per cent higher than the control.

In these two tests an effort was made to find whether etherizing the twigs caused any effect—direct or indirect—on the temperature. In Table XVI the figures showed that the temperature remained the same in both jars throughout the experiment. In the next test, however, there was a difference in the temperatures of the two jars beginning with the first observation, after 4½ hours, and continuing up to the last, there being as much as 1.1 degrees C. more warmth in the etherized jar, than in the control. This is very surprising when it is remembered that ether, in vaporizing, is expected to lower the temperature, and that transpiration also is a cooling process. On the other hand it is well known that considerable heat may be generated bv respiration. In this case, because readings were not taken frequently enough and owing to the fact that the methods were not very exact, it is difficult to say with anv degree of certainty whether the amount of heat generated was really sufficient to overcome the process of cooling apparently indicated by the data. This is a special problem in connection with the main question of the nature of the rest period and the actual effects of anesthetics in arousing dormant or "resting" plants into growth. Additional experiments are planned to be carried out next winter and in the meantime the figures in Table XVII are submitted for what they are worth.

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RESEARCH BULLETIN NO. 2.

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COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

A Study of the Cause of Wide Variation in Milk Production by Dairy Cows

COLUMBIA, MISSOURI
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A STUDY OF THE CAUSE OF WIDE VARIATION IN MILK PRODUCTION BY DAIRY COWS.

C. H. ECKLES and O. E. REED.

It is a well understood fact that cows under all conditions vary widely in both quantity of milk and fat produced, and in the economy of this production. It is not uncommon, and in fact is usually found that in a herd of ordinary size certain animals will produce twice as much milk and butter fat, or even more, during the year as other animals of the same age, of the same breeding, and having the same feed and care.

The importance to the producer of dairy products of taking advantage of this wide variation in economy of production has been emphasized very strongly in recent years by experimental work and by investigations of actual conditions as they exist among the dairy cattle of the country. The exact cause of this wide difference in economy of production has not as yet been pointed out. The investigation here reported was taken up for the purpose of determining the real cause of this difference. This line of work was suggested by the striking difference in production of two cows in the College herd.

These cows are registered Jerseys and are a little more than half sisters, the sire being the same and the mothers distantly related. The better cow of the two is Pedro's Ramaposa 181160, designated in this report by her herd number, No. 27. The inferior cow is Pedro's Elf 197242, designated as No. 62. These cows were raised under practically the same conditions according to the usual plan followed in our herd. They were fed their mothers' milk for some two weeks and then changed to skim milk. With this skim milk was fed a small amount of corn meal with hay in the winter and grass in the summer. Table 1 gives the facts in detail regarding the age and production of these two cows through the first two milking periods.

TABLE I.

PRODUCTION OF NO. 27 AND NO. 62, FIRST TWO LACTATION PERIODS.

	No. 27.	No. 62.
Date of birth	Sept. 4, 1902.	May 11, 1903.
Age at first calving	29 mo.	18 mo.
Lbs. milk first lactation period	4552	878
Lbs. fat first lactation period	238.8	44.1
No. days in milk	337	131
Lbs. milk second lactation period	7174	3189
Lbs. fat second lactation period	377	114.8
No. days in milk	365	282

Table 2 gives a summary to date of the milk and fat records of all the daughters of Minette's Pedro, the sire of these two cows, that have been in the herd.

TABLE II.

RECORDS OF THE DAUGHTERS OF MINETTE'S PEDRO.

	No. Lactation Periods.	Av. Lbs. Milk.	Av. Lbs. Fat.
Pedro's Ramaposa	3	6750	365.8
Pedro's Elf	3	2225	109.4
Pedro's Alphea Elf	5	6151	309.8
University May	3	4723	227.0
Columbia Huguita	5	6322	273.1
Pedro's Daisy Bate	2	3456	193.7
Missouri Daizie	1	4910	205.5
University Daizie	4	7746	405.6
University Stella	3	5336	273.7
University Elf	4	5053	247.3
University Belle	3	4960	223.8
Pedro's Grace Briggs	3	4909	287.9
Pedro's Matron	3	6582	355.9
Miss Missouri	3	6844	331.0
Pedro's Emily Harris	3	5271	238.5
Pedro's Estella	2	8807	462.1
Pedro's Alphea Ward	1	4728	267.0
Pedro's May Hubbard	4	4073	184.9
Pedro's Virginia Meredith	3	5776	320.6

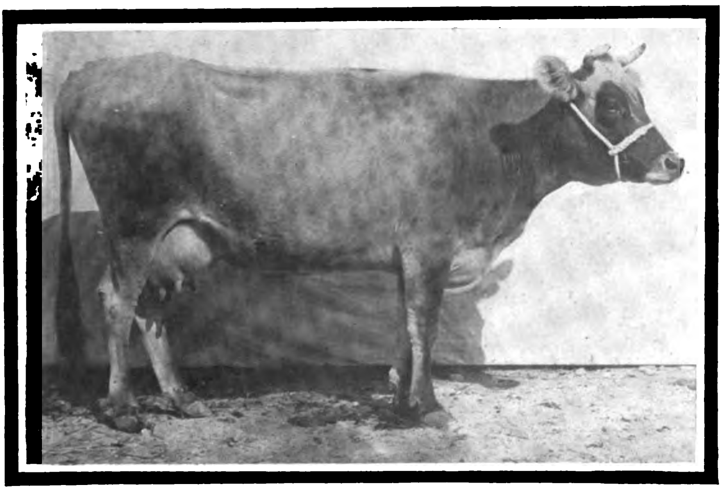
It will be noted that here we have a typical illustration of the wide variations that occur in the productive capacity of dairy cattle, even where they are of almost identical breeding and where conditions under which they are raised and kept are the same. Taking the production of the first two years together No. 27 produced 2.8 pounds of milk and 3.9 pounds of fat for each pound produced by No. 62. These two cows are not the only extremes in dairy capacity among the daughters of Minette's Pedro, as will be noted from Table 2. Two others have made records for a year above the best made by No. 27, while one other at least is as inferior as No. 62.

While the second milking period of these two cows was in progress and the wide variations above noted were observed in the production of the two animals an investigation was planned for the purpose of determining accurately the real cause of this extreme difference in efficiency as dairy cows. It was believed that if the cause of the variation in production between these two cows could be determined accurately, it would largely solve the question as to the variations in productive capacity among dairy cows in general.

With this purpose in view the cows were bred so that the calves might be born as near as possible at the same time. No. 62 calved October 4, 1907, and No. 27, October 7.

Possible Causes of the Variation in Production.—In considering this subject with the object of preparing plans for an investigation the author concluded that the possible causes of variation must be among those given below. These statements are arranged in the reverse order of what was judged to be the probable importance:

A. Variation in the ration of maintenance.
B. Difference in the co-efficient of digestion of food by the two animals.
C. The production of body fat by the inferior producer from a portion of the ration given above maintenance.
D. Difference in the amount of food consumed and used in excess of the ration of maintenance.



NO. 27, PEDRO'S RAMAPOSA 181160.

Discussion of Possible Causes.—(A) It was not anticipated that there would be any marked difference found in the ration of maintenance, although it was considered possible so that it would have to be taken into account. To determine the ration of maintenance it would be necessary to keep the two animals for some time while farrow under maintenance conditions.

(B) The consensus of opinion among recognized authorities on animal nutrition seems to be that while the data regarding the coefficient of digestibility with different animals is inadequate and conflicting, there is at present no reason for believing that there is any marked variation with individuals regarding the power of digestion.

However, this possibility is one that has to be considered in such investigations as this and eliminated if of no importance. To determine this, digestion trials made while producing milk would be necessary.

(C) The possibility of the inferior cow using the excess feed for depositing fat on the body is suggested by practical observation which indicates that inferior milkers are liable to take on fat. This, in some cases, might be sufficient explanation of the variation in production by different dairy cows. In planning the experiment it seemed best to control this factor rather than attempt to measure it and with this object in view it was planned to maintain the cows at a uniform weight, and in this way eliminate this possibility. It is evident in considering this question that there is a limit to the deposition of fat on the body of the animal having such a tendency and that the consumption of food must necessarily be smaller at some time during the year with such an animal than with a heavy producer. If the cow fattens while producing milk she will need to accumulate little, if any, fat while dry before beginning her next milking period and for this reason will need a light ration while dry. On the other hand. the heavy milking cow may be rather thin at the end of the milking period and continue eating heavily while dry in order to accumulate the normal amount of fat on the body before the beginning of the next milking period.

(D) In analyzing the subject it was believed the main possibility for variation lay in the difference in the amount of food consumed and used by the cows above the amount required for maintenance. If one cow is born with the characteristic of producing large quantities of milk this will result in a correspondingly large demand for nutrients to replace that drawn from the body. This will result in the cow consuming large quantities of feed above maintenance. It is a common observation that heavy milk producing cows are heavy eaters. Another cow with less capacity and tendency to produce milk will not have as much removed from her body in the way of nutrients and, therefore, she will have a smaller appetite. In the case of an animal of this type it would be safe to assume that if fed *ad libitum* she will store fat on the body for a time until the tissues are well filled, then the appetite will drop until she will consume not more than is necessary to furnish maintenance and sufficient material for the milk she is producing. If it is assumed that the nutrients for maintenance will be the same for animals having wide difference in capacity for production, the economy of production, that is, the amount of feed required to produce a given quantity of milk or fat might vary immensely from this cause alone.

Plan of Experiment.—The following statement gives the plan as made some months before the beginning of the investigation. It was carried out exactly as prepared.

"The first thing to be determined is the amount of food consumed by each animal. Both are to be given the same ration; that is, the grain mixture and the proportion between the amount of roughness and the grain is to to be the same for both. This proportion can be changed at any time when conditions seem to indicate that it is necessary but when it is changed for one it is to be changed for the other. The ration is to be adapted to the heavier producing cow. The grain ration shall consist of a mixture of at least three grains, preferably corn, bran, and oilmeal, and for roughness corn silage and alfalfa hay. A considerable quantity of each of these feeds, except the silage, is to be set aside for the exclusive use in this experiment in order to have as little change as possible in the composition of the feed. Each lot of feed used shall be sampled for chemical analysis. Both animals are to be fed sufficient food to maintain the body weight as near constant as possible. Both cows are to be given as large a ration as they will consume unless they begin using it for a gain in weight. It is probable that at least with No. 27 the weight will decrease for four or five weeks, regardless of how she is fed but this declining weight is to be checked as soon as possible and then kept at a uniform weight, or allowed to gain slowly until she returns to the original weight at the beginning of the milking period. Each animal is to be weighed at a stated time each day and a record of these weights kept. Accurate records are to be kept of the grain and roughness fed and of the amounts of each which may be refused. The refused feed of each animal is to be kept separate in a burlap sack and at intervals of ten days a sample is to be taken which represents the two mixed together. The dry matter in this sample is to be determined at once in the chemical laboratory and later a complete analysis is to be made. The same sample will be sufficient for both animals.

The two cows are to be placed in adjoining stalls and the same routine in general followed as is usual with the dairy herd. Care must be taken that the cows are not allowed access to any feed other than that in the regular ration. One man shall have complete charge of the two animals and do all the barn work connected with the experiment, if practical. Careful notes must be kept of any unusual conditions observed and general observations recorded regarding the condition of the animals, feeding characteristics, etc.

Sampling and Analyzing the Milk.—The milk produced by each cow is to be weighed in the usual manner and the weight recorded on the sheet in the barn. Pint glass bottles marked with the number

of the cow and labeled morning and night are to be used for holding the samples. The milker is to mix the milk thoroughly with a dipper and fill the proper bottle about two-thirds full of the milk, placing a paper cap on the top of the bottle on which is marked the number of pounds of milk produced by the cow at that milking. This milk is to be brought to the Dairy Laboratory at each milking. The person having the sampling in charge takes a composite sample from this original sample by taking a definite number of cubic centimeters per pound of milk with a graduated pipette and placing it in a two-quart jar properly labeled. When the first lot of milk is placed in this jar, one cubic centimeter of formaldehyde is to be added and later at the end of the ten day period covered by the composite sample another one-half centimeter is to be added.

The composite samples made as described will cover ten days each, corresponding to the ten-day periods into which the experiment is to be divided. The samples, when complete, are to be analyzed by the chemist for fat, nitrogen, sugar and ash.

Digestion Experiment.—During the early part of the milking period, preferably about the third month, a digestion experiment is to be conducted with these two animals. Care must be taken that the ration is properly adjusted to preserve constant weight and that they have been getting the same ration for at least a month before this time in order that conditions may be entirely normal. About two weeks before this experiment begins the cows should be accustomed to being watered in the stable and to being kept in during the day in order that conditions may not be abnormal when the digestion trial is under way. The digestion trial will probably cover ten days time.

Maintenance Experiment.—Both cows are to be kept farrow and after both are dry, a maintenance experiment is to be conducted for at least 90 days using a ration of the same composition, or approximately the same, as fed while they were producing milk."

In most investigations with dairy cows, as, for example, feeding trials, the results are measured in three terms: i. e., feed consumed, milk and fat produced and gain or loss in live weight. It will be noted that the plans as drawn eliminated one of these factors making it possible to measure the results in two factors—feed consumed and milk and fat produced. In the beginning four possible causes of the variation between the two cows was given. All four of these are provided for by the plan.

(A) By a maintenance experiment at the end of the milking period with the cows farrow.

(B) By a digestion trial when the cows were at their best production.

(C) Eliminated by maintaining constant weight.

(D) Uniform ration for the two and complete feed records and analyses of feed consumed and milk produced.

Summary of the Plan.—The following gives a summary of the plan as drawn and as carried out:

1. Complete record of amount and composition of feeds consumed.
2. Ration fed the two cows to be of the same composition at all times, the amount to be varied to suit the individual.
3. Cows to be kept at uniform weight.
4. Complete records made of milk produced and of its composition.
5. Cows to be kept farrow.
6. Digestion trial to be conducted when the cows are at their maximum production.
7. Cows to be kept on maintenance for at least three months at end of milking period to determine maintenance. Maintenance ration to be of same composition as that fed when producing milk to determine maintenance in terms of typical dairy ration.

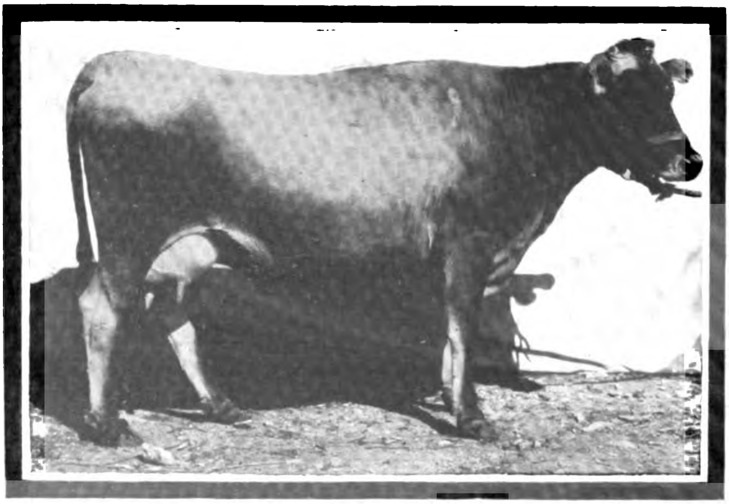
Ration.—The ration selected for the two cows was alfalfa hay, corn silage and a grain mixture of which corn composed 4 parts, bran 2 parts, and oilmeal 1 part. The grain ration was made up in the same proportions throughout the entire year. The alfalfa hay used was of the grade known as "Choice." The hay was cut in an ordinary cutting box before being fed. The silage was of good quality, made from well matured corn in the usual manner.

Beginning with April 2nd green alfalfa was fed until the 24th of July when green corn was substituted and fed until the 15th of September as shown by the feed record in Table 5. During a portion of this time silage was also fed and a portion of the time green feed was fed alone. When feeding silage or green feed a composite sample was taken by placing a small sample of the feed fed each day in a glass container in which a small amount of chloroform was kept to prevent decomposition. The moisture was determined in the composite sample at the end of 10 days and a sample for chemical analysis made up by adding three or more of the air dry samples together.

Feeding and Management.—The two cows were kept in adjoining stalls in the barn during the night and a portion of the day when the weather conditions were unfavorable outside. They were turned outdoors in a lot each day where they had access to water which was warmed by a tank heater in cold weather. They had no possible opportunity to gain access to food except what was fed them in the barn. They were fed twice daily at the usual time for feeding the remainder of the herd, in the morning and evening. The grain was first fed and then the roughness. The hay was all fed in the evening after the grain was consumed while the silage or green feed was fed twice daily.

The same man milked both these cows in all cases. The animals were observed closely each day and notes made at frequent intervals regarding their condition. It was found unnecessary to make provision for weighing back feed as was anticipated when making the plan, since during the entire period of winter feeding there was scarcely 20 pounds of refused feed and this was mostly cobs from corn in the silage. The animals remained in exceptionally good health throughout the period covered by the experiment. Each animal was, on two occasions, given a dose consisting of from 1 to 1¼ pounds Epsom salts on account of slight indications of indigestion.

It was observed in general that No. 27 when producing the maximum milk yield, was practically to the limit of her capacity for handling food. It was judged from observation that during the months



NO. 62, PEDRO'S ELF 197242.

while producing the maximum amount of milk she would have consumed more grain but that she would not have consumed any more roughness. Her maximum capacity for food seemed to coincide closely with the amount necessary to maintain her at uniform weight. No. 62 consumed all her feed at all times and it was judged from observations that she would have taken a small amount additional had it been offered although she at no time showed lack of food. In observing the two animals at feeding it was very evident that No. 27 had much the stronger appetite. She ate her feed rapidly, swallowed the grain with much less chewing and always showed by her impatience to get her feed a much keener appetite than did No. 62. Both animals remained in splendid physical condition throughout the entire investigation with the slight exception noted.

The digestion experiment was carried out as planned beginning on December 28, 1907 and continuing for 10 days. The daily ration was varied in quantity only when the live weight showed a gain or a loss. Weights were taken each morning after feeding and before watering. In studying the daily variation in weights it was found convenient to plot them at intervals of three or four days on sectional paper in order that the general trend might be better understood.

The average weights by 10 day periods are shown in Tables 4 and 5. It will be noted that No. 27 averaged 924 for the first period which consisted of only six days and then declined until the third period where the average weight was 846. This decline was foreseen in preparing the plan. It is impossible to feed a heavy milking cow a sufficient ration during the first month after calving to prevent a loss in weight. With No. 27 we assumed that if we replaced the weight lost the general result would be the same as it would have been had the weight been kept at a uniform point. With this object in view her weight was allowed to increase slightly during the greater part of the year. The intention was to close the year with the weight at practically the same point at which it was started. The table shows that during the last ten day period the average weight was 946 pounds, a gain of 22 pounds from the average weight in the first period. This gain, however, is very small in view of the fact that the period covered by the experiment is an entire year. As was expected, No. 62 did not decline in weight to any extent after calving. On account of the smaller production of milk it was found much easier to maintain her weight fairly constant than was the case with No. 27. The variations as shown by the average for to day periods are found in Table 5. While it was the intention to keep her at uniform weight, as a matter of fact there was a slight gain during the year since the average weight for the first 10 days was 888 pounds and for the last period of six days, 907. This gain, however, was practically the same for both animals and since it is so small it is not taken into account in our calculations. The usual difficulties were experienced in attempting to maintain the uniform weight. Whenever the ration is changed in character, as, for example, silage taken from the ration or added, the animals seem to change to a somewhat different plane due undoubtedly to a difference in the contents of the alimentary canal. Table 3 gives the daily variations in the weights of the two cows in two representative periods. This gives a fair idea of the ordinary variation from day to day.

TABLE 3.

DAILY VARIATIONS IN WEIGHTS OF NO. 27 AND NO. 62.

(In Two Periods.)

Jan.	No. 27	No. 62	April	No. 27	No. 62
14	898	898	3	900	910
15	880	910	4	920	910
16	875	890	5	885	910
17	880	885	6	900	925
18	870	890	7	895	920
19	895	890	8	890	920
20	885	880	9	900	930
21	875	895	10	890	920
22	870	900	11	910	925
23	890	900	12	910	915
Average	882	894		900	919

No. 62 showed the same characteristics as in her two former milking periods and declined rapidly in milk production after four or five months. She was dried up on the 20th of August when she was producing about 3 pounds of milk a day, but the feed records cover the full 365 days. No. 27 continued to produce milk throughout the entire 365 days. At the close of her year she was producing approximately 14 pounds a day. Tables 4 and 5 give the average weights and a summary of the feed consumed by each of the two animals by 10 day periods. Tables 6 and 7 give a summary of the food constituents. It will be noted that the food constituents are not calculated digestible nutrients but the amount of the several constituents as found by chemical analysis of the food consumed.

TABLE 4.

Cow No. 27.

SUMMARY OF FEED CONSUMED.

(Weights in Pounds.)

Period No.	Date.	Grain.	Alfalfa Hay.	Silage.	Green Feed.	Average Weight of Cow.
1	10-10—10-15	44	54	180	...	924
2	10-16—10-25	72	91	125	...	857
3	10-26—11- 4	75	90	265	...	846
4	11- 5—11-14	105	90	350	...	861
5	11-15—11-24	110	90	350	...	890
6	11-25—12- 4	110	90	350	...	879
7	12- 5—12-14	110	90	350	...	872
8	12-15—12-24	110	90	350	...	861
9	12-25— 1- 3	110	90	350	...	873
10	1- 4— 1-13	110	90	365	...	865
11	1-14— 1-23	110	88.5	370.5	...	882
12	1-24— 2- 2	110	90	326.7	...	865
13	2- 3— 2-12	110	83	338	...	875
14	2-13— 2-22	110	90	331	...	872
15	2-23— 3- 3	110	90	328	...	885
16	3- 4— 3-13	110	89	350	...	883
17	3-14— 3-23	110	90	325	...	897
18	3-24— 4- 2	101	90	300.5	...	888
19	4- 3— 4-12	100	90	320	...	900
20	4-13— 4-22	94	86	310	12	902
21	4-23— 5- 2	90	56	269	135	899
22	5- 3— 5-12	90	50	220	268	902
23	5-13— 5-22	90	79	191	314	914
24	5-23— 6- 1	90	56	233	300	924
25	6- 2— 6-11	83	50	219.8	260.8	925
26	6-12— 6-21	80	50	234.4	274.4	929
27	6-22— 7- 1	80	45.6	168.3	184.3	926
28	7- 2— 7-11	80	50	120.1	297.4	932
29	7-12— 7-21	80	76	...	304.1	899
30	7-22— 7-31	80	80	...	289.2	901
31	8- 1— 8-10	80	80	...	400	906
32	8-11— 8-20	80	80	...	400	928
33	8-21— 8-30	80	80	...	400	935.5
34	8-31— 9- 9	80	80	...	326	938
35	9-10— 9-19	80	80	160	160	938.5
36	9-20— 9-29	80	80	315.1	...	937.5
37	9-30—10- 9	80	80	312.2	...	956.5
Total		3424	2904.1	8777.9	4325.2	...

TABLE 5.

Cow No. 62.

SUMMARY OF FEED CONSUMED.

(Weights in Pounds.)

Period No.	Date.	Grain.	Alfalfa Hay.	Silage.	Green Feed.	Average Weight of Cow.
1	10- 6—10-15	74	90	30	...	883
2	10-16—10-25	62	85	49.5	...	875
3	10-26—11- 4	58	78	204	...	882
4	11- 5—11-14	62	54.5	206	...	882
5	11-15—11-24	70	60	220	...	884
6	11-24—12- 4	70	60	220	...	882
7	12- 5—12-14	70	60	220	...	880
8	12-15—12-24	70	60	220	...	894
9	12-25— 1- 3	70	60	220	...	895
10	1- 4— 1-13	70	60	230.5	...	896
11	1-14— 1-23	70	60	244.5	...	894
12	1-24— 2- 2	70	60	220	...	898
13	2- 3— 2-12	62.8	55.8	210.2	...	875
14	2-13— 2-22	65	53	207	...	872
15	2-23— 3- 3	63.5	51.4	200.2	...	912
16	3- 4— 3-13	60	49	190	...	906
17	3-14— 3-23	60	49	190	...	909
18	3-24— 4- 2	60	53.5	208	...	907
19	4- 3— 4-12	60	54	210	...	919
20	4-13— 4-22	54	47.6	177.4	12	913
21	4-23— 5- 2	50	20.9	155.2	84.9	910
22	5- 3— 5-12	50	28	125.1	148.4	910
23	5-13— 5-22	50	44	108.7	172.1	919
24	5-23— 6- 1	50	31.3	136.5	166	925
25	6- 2— 6-11	45	27.1	129.4	160.7	926
26	6-12— 6-21	40	25	123.7	145	923
27	6-22— 7- 1	40	25	124.6	117.5	931
28	7- 2— 7-11	33	21.1	55	185	929
29	7-12— 7-21	30	28.6	...	120.3	911
30	7-22— 7-31	30	30	...	117	897
31	8- 1— 8-10	34	34	...	170	884
32	8-11— 8-20	37	37	...	185	905.7
33	8-21— 8-30	9	37	...	185	913
34	8-31— 9- 9	30	30	...	123	906
35	9-10— 9-19	30	30	60	60	904.5
36	9-20— 9-29	30	30	120	...	911
37	9-30—10- 5	18	18	72	...	907
Total for year		1907.3	1697.8	5087.5	2101.9	

TABLE 6.

Cow No. 27.

SUMMARY OF FOOD CONSTITUENTS.

(Weights in Pounds.)

No. Period	Date.	Dry Matter.	Protein.	Nitrogen-free Extract.	Crude Fibre.	Ether Extract.	Ash.
1	10-10—10-15	126.523	17.245	69.385	27.575	4.229	8.168
2	10-16—10-25	149.223	11.710	25.373	39.544	5.759	11.710
3	10-26—11- 4	204.644	26.085	106.764	51.545	6.678	13.626
4	11- 5—11-14	248.282	31.599	134.431	57.860	8.636	15.821
5	11-15—11-24	252.639	32.280	137.479	58.098	8.866	15.968
6	11-25—12- 4	252.639	32.280	137.479	58.098	8.866	15.968
7	12- 5—12-14	283.124	33.379	160.394	62.615	9.353	17.430
8	12-15—12-24	283.124	33.379	160.394	62.615	9.353	17.430
9	12-25— 1- 3	283.124	33.379	160.394	62.615	9.353	17.430
10	1- 4— 1-13	287.518	33.678	163.080	63.677	9.476	17.677
11	1-14— 1-23	287.716	33.598	163.467	63.522	9.499	17.702
12	1-24— 2- 2	276.299	32.914	156.298	60.965	9.160	17.008
13	2- 3— 2-12	282.256	34.809	165.014	48.782	16.547	17.105
14	2-13— 2-22	286.838	35.604	165.629	50.509	17.373	17.720
15	2-23— 3- 3	285.902	35.536	165.045	50.324	17.319	17.675
16	3- 4— 3-13	291.817	35.893	168.927	51.404	17.683	17.909
17	3-14— 3-23	284.965	35.468	164.461	50.139	17.264	17.630
18	3-24— 4- 2	269.318	33.654	154.352	48.204	16.156	16.950
19	4- 3— 4-12	262.844	35.031	149.696	46.276	13.762	17.308
20	4-13— 4-22	252.992	34.501	143.238	45.948	12.948	16.424

TABLE 6. (*Continued.*)

Cow No. 27.

SUMMARY OF FOOD CONSTITUENTS.

(Weights in Pounds.)

Period. No.	Date.	Dry Matter.	Protein.	Nitrogen-free Extract.	Crude Fibre.	Ether Extract.	Ash.
21	4-23— 5- 2	240.351	34.080	134.971	44.094	11.784	16.204
22	5- 3— 5-12	256.398	38.634	137.835	50.312	11.677	18.622
23	5-13— 5-22	258.869	38.703	136.201	53.136	11.831	18.999
24	5-23— 6- 1	254.803	36.183	136.259	52.593	11.245	18.527
25	6- 2— 6-11	242.252	34.911	128.726	50.468	10.291	17.856
26	6-12— 6-21	257.019	37.352	134.609	55.230	10.862	19.464
27	6-22— 7- 1	212.265	31.275	113.140	43.048	9.841	15.460
28	7- 2— 7-11	269.573	37.641	144.548	59.445	10.789	17.148
29	7-12— 7-21	256.619	45.092	120.620	59.257	9.875	21.773
30	7-22— 7-31	215.284	33.424	112.324	45.098	8.736	15.694
31	8- 1— 8-10	233.104	31.789	127.712	48.162	9.960	15.472
32	8-11— 8-20	249.204	32.061	133.500	53.216	9.918	17.706
33	8-21— 8-30	262.704	32.969	141.680	58.298	10.204	19.544
34	8-31— 9- 9	278.151	35.705	153.087	59.492	11.567	18.341
35	9-10— 9-19	246.427	31.633	134.697	54.462	9.941	15.685
36	9-20— 9-29	239.553	30.762	131.251	52.583	9.613	15.334
37	9-30—10- 9	238.778	30.699	130.806	52.390	9.586	15.283
Total .		9362.636	1224.935	6333.097	1951.590	404.995	521.798

TABLE 7.

Cow No. 62.

SUMMARY OF FOOD CONSTITUENTS.

(Weights in Pounds.)

Period.	Date.	Dry Matter.	Protein.	Nitrogen-free Extract.	Crude Fibre.	Ether Extract.	Ash.
1	10- 6—10-15	155.886	24.296	86.182	30.856	5.228	9.856
2	10-16—10-25	145.018	21.854	70.340	32.940	4.675	9.489
3	10-26—11- 4	165.975	21.228	85.428	42.861	5.285	11.215
4	11- 5—11-14	147.755	18.820	79.785	34.620	5.116	9.444
5	11-15—11-24	162.777	20.842	88.150	37.780	5.666	10.360
6	11-24—12- 4	162.777	20.842	88.150	37.780	5.666	10.360
7	12- 5—12-14	181.939	21.538	102.553	40.644	5.972	11.266
8	12-15—12-24	181.939	21.538	102.553	40.644	5.972	11.266
9	12-25— 1- 3	181.939	21.538	102.553	40.644	5.972	11.266
10	1- 4— 1-13	185.014	21.742	104.899	41.388	6.059	11.457
11	1-14— 1-23	189.115	22.021	106.860	42.379	6.174	11.710
12	1-24— 2- 2	181.939	21.538	102.558	40.644	5.972	11.266
13	2- 3— 2-12	174.498	21.445	100.890	31.289	10.060	10.860
14	2-13— 2-22	172.884	21.271	100.019	30.499	10.466	10.626
15	2-23— 3- 3	167.908	20.682	97.167	29.567	10.176	10.812
16	3- 4— 3-13	159.822	19.622	92.147	28.106	9.645	9.800
17	3-14— 3-23	159.822	19.622	92.147	28.106	9.645	9.800
18	3-24— 4- 2	169.229	20.665	97.446	30.463	10.134	10.519
19	4- 3— 4-12	162.367	21.452	92.928	28.853	8.444	10.689
20	4-13— 4-22	144.712	19.763	82.005	26.218	7.394	9.400

TABLE 7. (*Continued.*)

Cow No. 62.

SUMMARY OF FOOD CONSTITUENTS.

(Weights in Pounds.)

Period.	Date.	Dry Matter.	Protein.	Nitrogen-free Extract.	Crude Fibre.	Ether Extract.	Ash.
21	4-23— 5- 2	127.946	17.955	78.114	22.590	6.323	8.457
22	5- 3— 5-12	143.819	21.543	77.108	23.126	6.522	10.401
23	5-13— 5-22	148.972	21.554	75.972	29.303	6.627	10.518
24	5-23— 6- 1	143.708	20.256	76.966	29.738	6.810	10.442
25	6- 2— 6-11	138.502	19.922	78.196	29.316	5.786	10.383
26	6-12— 6-21	132.395	19.184	69.210	28.659	5.268	10.077
27	6-22— 7- 1	126.806	18.085	67.086	26.964	5.177	9.467
28	7- 2— 7-11	118.049	16.372	63.123	26.408	4.614	7.586
29	7-12— 7-21	98.660	17.367	46.179	22.944	3.745	8.425
30	7-22— 7-31	82.560	12.757	43.041	17.400	3.329	6.039
31	8- 1— 8-10	99.069	18.511	54.278	20.469	4.284	6.575
32	8-11— 8-20	116.029	14.832	61.805	24.696	4.586	8.214
33	8-21— 8-30	96.289	11.294	48.224	25.619	3.056	8.046
34	8-31— 9- 9	104.606	13.415	57.557	22.385	4.348	6.397
35	9-10— 9-19	92.410	11.862	50.511	20.423	3.728	5.882
36	9-20— 9-29	80.383	11.580	49.534	19.355	3.623	5.786
37	9-30—10- 5	54.280	6.948	29.721	11.914	2.174	3.472
Total .		5027.682	690.781	2890.880	1103.529	223.121	349.319

A summary of the total feed and food constituents consumed by the two animals is shown in the following statements:

FEED CONSUMED DURING THE YEAR.

Summary of Tables 4 and 5.

(Weights in Pounds.)

No.	Grain.	Alfalfa Hay.	Green Feed.	Silage.
27	8424	2904	4825	8778
62	1907	1698	2102	5088

FOOD CONSTITUENTS CONSUMED DURING THE YEAR.

Summary of Tables 6 and 7.

(Weights in Pounds.)

No.	Dry Matter.	Protein.	N. fr. Ex.	Crude Fibre.	Ether Extract	Ash.
27	9862.6	1224.9	6833.1	1951.6	405.0	521.8
62	5927.6	690.7	2890.9	1102.5	223.1	849.8

RATIO OF FEED CONSUMED BY NO. 27 TO THAT USED BY NO. 62.

	No. 62.	No. 27
Grain	1	1.79
Hay..	1	1.71
Silage	1	1.72

It will be noted from the statement above that the plan to keep the ration of the same composition for each was carried out closely. At certain times the ration of one was changed slightly for some reason and this accounts for the slight variation in ratio of the grain, hay and silage. In general No. 27 consumed 1.75 pounds of feed for 1 pound consumed by No. 62.

Tables 8 and 9 give the yield of milk by 10 day periods for the two cows and the analyses of the composite samples representing these periods. Tables 10 and 11 give the yield of milk constituents by periods and the totals for the complete lactation periods.

TABLE 8.

YIELD OF MILK AND AVERAGE COMPOSITION.

No. 27.

Period.	Lbs. Milk.	% Fat.	% Nitrogen.	Protein. N x 6.38.	Sugar.	Ash.
1	181.3	4.20	.52	3.32	5.00	.745
2	292.6	6.20	.52	3.32	4.70	.744
3	310.4	5.60	.52	3.32	5.30	.745
4	325.5	5.25	.55	3.51	5.00	.723
5	314.3	5.30	.56	3.57	3.55	.736
6	289.2	5.10	.58	3.70	3.76	.730
7	287.6	6.60	.59	3.76	4.40	.764
8	283.0	5.40	.58	3.70	4.86	.698
9	272.3	5.10	.61	3.89	5.03	.762
10	274.9	5.60	.62	3.96	5.30	.691
11	266.7	5.10	.64	4.08	4.30	.721
12	240.5	5.60	.62	3.96	4.98	.677
13	243.1	5.80	.64	4.08	4.83	.750
14	234.6	5.75	.64	4.08	4.35	.727
15	245.6	5.60	.66	4.21	5.06	.776
16	243.9	6.75	.65	4.15	4.66	.812
17	244.2	5.70	.65	4.15	3.90	.775
18	235.0	5.70	.67	4.27	5.30	.771
19	231.6	5.60	.68	4.34	4.96	.789
20	242.3	5.60	.66	4.21	4.60	.787
21	243.9	5.50	.67	4.27	4.90	.787
22	236.6	5.55	.68	4.34	4.50	.758
23	218.4	5.50	.66	4.21	4.50	.754
24	222.2	5.70	.65	4.15	3.60	.852
25	204.0	5.90	.62	3.96	4.70	.841
26	191.1	5.70	.64	4.08	4.50	.767
27	178.8	5.70	.61	3.89	4.67	.711
28	194.3	5.50	.68	4.34	4.69	.660
29	189.3	5.40	.63	4.02	4.80	.704
30	182.8	5.40	.63	4.02	4.08	.655
31	183.5	5.00	.65	4.15	4.50	.672
32	182.2	5.30	.67	4.27	4.98	.646
33	173.7	5.70	.62	3.96	4.58	.597
34	184.9	5.60	.67	4.27	4.98	.660
35	161.6	5.60	.71	4.53	3.79	.705
36	162.6	5.80	.70	4.47	4.33	.708
37	149.4	6.00	.69	4.40	4.35	.689

TABLE 9.

YIELD OF MILK AND AVERAGE COMPOSITION.

(By Periods.)

No. 62.

Period.	Lbs. Milk.	% Fat.	% Nitrogen.	Protein N x 6.38.	Sugar.	Ash.
1	115.9	5.14	.63	4.02	5.08	.768
2	139.6	5.80	.63	4.02	4.85	.764
3	147.8	5.20	.63	4.02	5.80	.761
4	156.4	5.00	.62	3.96	3.42	.770
5	150.2	5.30	.62	3.96	6.48	.765
6	137.5	5.10	.63	4.02	3.41	.750
7	135.2	5.60	.63	4.02	3.98	.761
8	133.4	5.55	.63	4.02	4.61	.702
9	134.9	5.10	.65	4.15	4.55	.768
10	123.2	5.20	.62	3.96	5.00	.700
11	119.4	5.60	.62	3.96	4.23	.750
12	114.5	5.40	.63	4.02	4.48	.757
13	112.0	5.55	.62	3.96	3.93	.754
14	104.7	5.45	.65	4.15	3.52	.759
15	104.8	5.65	.66	4.21	6.18	.700
16	103.8	5.30	.65	4.15	4.48	.712
17	96.8	5.20	.63	4.02	3.88	.735
18	96.5	5.50	.64	4.08	4.85	.778
19	87.9	5.10	.66	4.21	4.51	.785
20	90.9	5.40	.60	3.83	4.30	.720
21	84.4	4.95	.58	3.70	5.00	.657
22	77.6	5.45	.64	4.08	4.70	.837
23	72.6	5.30	.61	3.89	4.40	.800
24	79.3	5.50	.60	3.83	3.50	.916
25	73.0	5.30	.62	3.96	4.50	.723
26	68.0	5.20	.64	4.08	4.20	.732
27	65.5	5.30	.63	4.02	4.40	.655
28	64.6	5.20	.60	3.83	4.61	.718
29	56.2	5.20	.59	3.76	4.58	.686
30	49.2	5.10	.58	3.70	4.55	.688
31	45.6	5.00	.60	3.83	4.50	.690
32	41.0	5.10	.60	3.83	4.25	.689

TABLE 10.

YIELD OF MILK CONSTITUENTS BY PERIODS.

No. 27.

Period.	Date—10 days. Ending.	Lbs. Milk.	Lbs. Fat.	Lbs. Nitrogen.	Lbs. Protein.	Lbs. Sugar.	Lbs. Ash.
	1907						
1*	October 15	181.3	7.615	.943	6.016	9.065	1.351
2	October 25	292.6	13.141	1.522	9.710	13.752	2.177
3	November 4	310.4	17.382	1.614	10.297	16.451	2.312
4	November 14	325.5	17.069	1.790	11.420	16.275	2.353
5	November 24	314.3	16.658	1.760	11.229	11.158	2.313
6	December 4	289.2	14.749	1.677	10.699	10.874	2.111
7	December 14	287.6	16.106	1.697	10.827	12.654	2.197
8	December 24	283.0	15.282	1.641	10.470	13.754	1.975
	1908						
9	January 3	272.3	13.887	1.661	10.597	13.697	2.075
10	January 13	274.9	15.394	1.704	10.872	14.570	1.900
11	January 23	266.7	13.602	1.707	10.891	11.468	1.923
12	February 2	240.5	13.468	1.491	9.513	11.977	1.628
13	February 12	243.1	14.100	1.556	9.927	11.742	1.823
14	February 22	234.6	13.490	1.501	9.576	10.205	1.706
15	March 3	245.6	13.754	1.621	10.342	12.476	1.906
16	March 13	243.9	14.024	1.585	10.112	11.866	1.980

* 6 days.

17	March 23	244.2	13.919	1.587	10.125	9.524	1.898
18	April 2	235.0	13.395	1.575	10.049	12.455	1.812
19	April 12	231.6	12.970	1.575	10.049	11.487	1.827
20	April 22	242.3	13.569	1.599	10.202	11.146	1.907
21	May 2	243.9	13.415	1.684	10.425	11.951	1.798
22	May 12	236.6	13.181	1.609	10.265	10.647	1.798
23	May 22	218.4	12.012	1.441	9.194	9.828	1.647
24	June 1	222.2	12.665	1.444	9.213	7.999	1.893
25	June 11	204.0	12.086	1.265	8.071	9.588	1.716
26	June 21	191.1	10.898	1.223	7.803	8.600	1.466
27	July 1	178.8	9.907	1.060	6.763	8.116	1.236
28	July 11	194.3	10.687	1.321	8.428	9.118	1.282
29	July 21	189.3	10.222	1.193	7.611	9.066	1.333
30	July 31	182.8	9.871	1.152	7.350	7.458	1.197
31	August 10	183.5	9.175	1.193	7.611	8.258	1.233
32	August 20	182.2	9.657	1.221	7.790	8.982	1.177
33	August 30	173.7	9.901	1.077	6.871	7.955	1.037
34	September 9	184.9	10.354	1.239	7.905	9.116	1.220
35	September 19	161.6	9.050	1.147	7.318	6.125	1.139
36	September 29	162.6	9.431	1.188	7.260	7.041	1.148
37	October 9	149.4	8.964	1.031	6.574	6.499	1.029
	Total	8522.9	469.965	58.194	339.875	392.458	62.508

TABLE II.

YIELD OF MILK CONSTITUENTS BY PERIODS.

No. 62.

Period.	Ten Days, Ending.	Lbs. Milk.	Lbs. Fat.	Lbs. Nitrogen.	Lbs. Protein.	Lbs. Sugar.	Lbs. Ash.
	1907						
1	October 15	115.9	5.957	.731	4.664	5.888	.884
2	October 25	139.6	8.097	.879	5.606	6.771	1.067
3	November 4	147.3	7.660	.928	5.921	7.807	1.121
4	November 14	156.4	7.820	.970	6.189	5.349	1.204
5	November 24	150.2	7.961	.931	5.840	9.733	1.149
6	December 4	137.5	7.013	.866	5.525	4.689	1.031
7	December 14	135.2	7.571	.852	5.436	5.813	1.029
8	December 24	138.4	7.681	.872	5.563	6.380	.972
	1908						
9	January 3	134.9	6.880	.877	5.595	6.138	1.036
10	January 13	123.2	6.406	.764	4.874	6.160	.862
11	January 23	119.4	6.686	.740	4.721	5.051	.896
12	February 2	114.5	6.183	.721	4.600	5.072	.867
13	February 12	112.0	6.216	.694	4.428	4.402	.844
14	February 22	104.7	5.706	.681	4.345	3.685	.795
15	March 3	104.8	5.554	.692	4.405	6.477	.734
16	March 13	103.8	5.501	.675	4.307	4.650	.739
17	March 23	98.8	5.138	.622	3.968	3.833	.726

18	April 2	96.5	5.306	.618	3.943	4.680	.751
19	April 12	87.9	4.483	.580	3.700	3.964	.690
20	April 22	90.9	4.909	.545	3.477	3.909	.654
21	May 2	84.4	4.178	.490	3.126	4.220	.555
22	May 12	77.6	4.229	.497	3.171	3.647	.650
23	May 22	72.6	3.848	.443	2.826	3.194	.581
24	June 1	79.3	4.362	.476	3.037	2.776	.726
25	June 11	73.0	3.869	.453	2.890	3.285	.528
26	June 21	68.0	3.536	.435	2.775	2.856	.498
27	July 1	65.5	3.472	.413	2.635	2.882	.429
28	July 11	64.6	3.359	.388	2.475	2.978	.461
29	July 21	56.2	2.922	.332	2.118	2.574	.386
30	July 31	49.2	2.509	.285	1.818	2.239	.338
31	August 10	45.6	2.280	.274	1.748	2.052	.315
32	August 20	41.0	2.091	.246	1.569	1.743	.282
	Total	3188.9	169.385	19.970	127.297	144.397	23.806

The statements below give a summary of the yield and average composition of the milk, the yield of milk constituents for the two cows, and the ratio between the yields of milk and milk constituents.

AVERAGE COMPOSITION OF MILK.

Summary of Tables 8 and 9.

Cow No.	Yield of Milk.	% Fat	% Nitrogen.	% Protein.	% Sugar.	% Ash.
27	8522.9	5.51	.624	3.98	4.60	.733
62	3188.9	5.31	.626	3.99	4.52	.746

COMPARISON OF YIELD OF MILK CONSTITUENTS.

Summary of Tables 10 and 11.

No.	Fat.	Nitrogen.	Protein.	Sugar.	Ash.
27	469.9	53.19	339.3	392.4	62.5
62	169.3	19.97	127.2	144.3	23.8

RATIO OF MILK AND MILK CONSTITUENTS PRODUCED BY THE TWO COWS.

Production of No. 62 represented by 1.

Milk.	Total Solids.	Fat.	Protein.	Sugar.	Ash.
1:2.67	1:2.72	1:2.77	1:2.66	1:2.71	1:2.62

It will be noted that No. 27 produced 2.67 pounds of milk and 2.77 pounds of fat for each pound yielded by No. 62.

In the beginning four possible causes of the variations in production were given under the letters A, B, C, D. It is now the purpose to discuss that data presented giving the feed consumed by the two animals during the year, and the production of milk and feed by each, with the view of showing its relation to these four possible sources of variation.

Maintenance Experiment.—It is not the purpose to give the full details regarding the maintenance experiment at this time. This data, however, will be presented in detail in a later publication. Only a summary and the totals are given which is necessary for making clear the relation of the results found by the maintenance test to the problem under consideration.

The maintenance experiment was carried out as originally planned with each of the two animals while dry and farrow. With No. 62 the

maintenance period begun August 31, 1907 and continued 180 days, ending February 26. The feed records given for the lactation period for No. 62 in Tables 4 and 6 cover the entire year of 365 days beginning October 6, 1907. The time included from August 31, 1908 to October 5, therefore, overlaps and in addition to being counted as part of the year including the lactation period, is also a part of the maintenance period. This is possible since No. 62 was dry after August 20th while No. 27 was milked for the full year. The maintenance period for No. 27 included 160 days beginning October 30th and continuing until April 7th.

As stated in the plan of the experiment in carrying out this maintenance trial the general plan was to use the same feeds as were fed during the milking period and in practically the same proportions with the purpose in view of determining in terms of the ration fed while the cows were producing milk, how much of this ration was required for maintaining the animal. It is appreciated by the author that such a ration is not an economical maintenance ration and that one consisting of roughness alone and containing a much smaller amount of protein than was fed should be selected if the aim be to determine the most economical ration for maintenance. Such has been the aim of others who have carried out what little investigation there has been reported on the maintenance of dairy cattle. The object in view, however, in this case was not to select the most economical ration or determine the proper proportion of constituents for maintenance, but to find what part of the normal ration fed while the cows were in milk was needed by the animal for maintenance. The grain ration fed during the period of maintenance consisted of corn 4 parts, bran 2 parts and oilmeal 1 part which was exactly the same proportion used throughout the milking periods of the two animals. The same kind and quality of hay and silage was also fed as was used during the milking periods. In all cases the two cows had exactly the same ration with the exception of the necessary variation in the amount used. The ratio between the grain mixture, hay and silage was 1:1:4 which was about the average proportion fed while the cows were in milk. The cows were kept under the same conditions as described for the period when in milk and the two animals received the same treatment in every way. They were weighed each morning after being fed and before having access to water. The usual difficulties were experienced in maintaining the weights at a uniform point. On the whole, however, the results were as satisfactory as can be expected judging from the work of other investigators along this line. Both animals made a slight gain in weight during the maintenance period. In No. 27 this amounted to 21 pounds in 160 days, and in No. 62, 18 pounds in 180 days.

TABLE 12.

SUMMARY OF FEED REQUIRED FOR MAINTENANCE.

	No. 27.		No. 62.	
Dates included	Oct. 30, 1908-April 7, 1909.		August 31, 1908-Feb. 28, 1909.	
No. days	160		180	
Average weight 1st 10 days.	881		906	
Average weight last 10 days.	902		922	
	Total.	Per Day.	Total.	Per Day.
Lbs. grain fed	525.9	3.29	526.4	2.92
Lbs. hay fed	527.9	3.30	526.4	2.92
Lbs. silage fed	2111.6	13.20	2116.6	11.76

Table 12 gives the data in regard to maintenance trial including the amount of hay, grain and silage used by each animal and the amount of each per day. The question was raised in the beginning regarding the possibility of variation in the amount required for maintenance. An examination of the data presented above shows that on the average No. 27 required a slightly larger amount of feed than did No. 62. It will be observed that the weight of the two animals is quite close and for this reason as well as for the fact that it interferes with the comparison from a practical standpoint the results are not calculated on a 1000 pound basis. On the average No. 27 consumed 3.27 pounds of grain per day for maintenance; No. 62 consumed 2.92 pounds and each had hay and silage in the same proportions. Below is given a comparison of maintenance requirements for an entire year. In calculating these figures it is assumed that the average food requirements found during the maintenance trial is the average for the entire year.

COMPARISON OF MAINTENANCE REQUIREMENT FOR ONE YEAR.

(Weights in pounds.)

	Grain.	Alfalfa Hay.	Silage.
No. 27	1200.8	1204.5	4818.0
No. 62	1065.8	1065.8	4292.4
Difference	135.0	138.7	525.6

It will be noted that on this basis it would require 135 pounds more grain, 138 pounds more alfalfa hay, and 525 pounds more silage to maintain No. 27 for a year than is required for No. 62. The data shows that undoubtedly there is a small difference in the maintenance require-

ments of these two animals. It is evident that this difference does not account in any way for the wide variation in the production of the two animals. In fact, No. 27, the larger producer, has the higher maintenance requirement. The only conclusion that can be drawn from this data is that in this case the factor of variation in maintenance requirement is so small that it may be ignored in attempting to explain the difference in the economy of production.

Digestion Trial.—Under B in the discussion of the possible causes of variation in production a possible difference in the coefficient of digestion by the two animals was given. A digestion trial covering 10 days time was carried out, under the direction of Dr. P. F. Trowbridge of the Department of Agricultural Chemistry, as called for by the plan. This digestion trial began December 27, 1907. It is not the intention to give complete data regarding this digestion trial at this time. A summary only will be given so far as it relates to the question under investigation and full details will be published later with other data of similar character.

At the time of carrying out the digestion trial the animals were close to their maximum production of milk. The digestion trial was carried out in the usual manner. All the feed to be fed during the ten days was weighed out in advance by weighing the ration for each day by itself into a closed bucket. At the same time samples were taken for chemical analysis. All the solid and liquid excretion of the animals was collected by attendants and subjected to chemical analysis. Below is given a statement of the ration fed daily to each animal during this digestion trial and the average yield of milk and fat.

DAILY RATION AND MILK YIELD.

10 Day Digestion Trial.

(Weights in Pounds.)

	No. 27	No. 62
Alfalfa Hay	9	6
Grain	11	7
Silage	35	22
Average milk yield	26.8	13.8
Average fat yield	1.37	.68

All the data necessary for studying the relation of the digestion trial to the problems under consideration is given in Tables No. 13 and 14. These tables give a summary of the feed constituents consumed by each animal, the amount of each excreted, and the per cent digested.

TABLE 13.

SUMMARY OF RESULTS—10-DAY DIGESTION TRIAL.

No. 27.

(Weights in Grams.)

	Consumed.	Excreted in Dung.	% Digested.
Protein	15094.44	6225.06	58.75
Fat	4228.80	1897.43	66.95
Crude Fibre	28090.08	12972.22	53.82
Nitrogen-free Extract	65982.21	19775.26	70.08
Total	113395.53	40869.96	64.39

TABLE 14.

SUMMARY OF RESULTS—10-DAY DIGESTION TRIAL.

No. 62.

(Weights in Grams.)

	Consumed.	Excreted in Dung.	% Digested.
Protein	90566.48	3771.25	60.58
Fat	2686.82	1079.39	59.82
Crude Fibre	17782.97	8198.14	53.89
Nitrogen-free Extract	41922.09	12143.83	71.04
Total	71958.86	25192.61	64.99

It will be noted by studying these figures that there is some variation in the per cent of the different food constituents digested by the two animals but in no case is the variation of any great extent. Taking the average digestion coefficient, as the per cent digested of the total constituents consumed, it will be observed that the results are remarkably close, No. 27 showing 64.39 per cent digested and No. 62, 64.99. It is evident from the above results that the wide variation in the production of these two animals cannot be attributed in any way to a difference in the power to digest food. The variation is less than would have been anticipated with any two animals that might have been selected regardless of dairy qualities.

(D) In the discussion of the possible sources of variation it was assumed that the main possibility lay in a difference in the amount of food consumed and used in excess of the ration of maintenance. It has been shown by Tables 4 and 5 that there was considerable difference

in the amount of feed consumed during the year by the two cows and that No. 27 consumed 1.75 pounds of feed for every pound consumed by No. 62. A summary of the amount of feed consumed and the food constituents for the two cows is given on page 123

In Tables 15 and 16 is shown what part of the ration given the two cows was available for milk production. This table is made up by taking the first row of figures, the totals of feed consumed from Tables 4 and 5, and the second row, the estimated maintenance for the year, calculated as previously shown (P. 26), from the maintenance period of 160 days with No. 27 and 180 days with No. 62.

TABLE 15.

SHOWING PORTION OF RATION AVAILABLE FOR MILK PRODUCTION.

No. 27.

(Weights in Pounds.)

	Grain.	Hay.	Silage.	Green Feed.
Consumed during year in milk	3424.0	2904.0	8778.0	4325.0
Maintenance for year	1200.8	1204.5	4818.0	......
Available for milk production.	2223.2	1699.5	3960.0	4325.0

TABLE 16.

SHOWING PORTION OF RATION AVAILABLE FOR MILK PRODUCTION

No. 62.

(Weights in Pounds.)

	Grain.	Hay.	Silage.	Green Feed.
Consumed during year in milk	1907.0	1698.0	5088.0	2102.0
Maintenance for year	1065.8	1065.8	4292.4	......
Available for milk production.	841.2	632.2	795.6	2102.0

Attention will at once be drawn to the large proportion of the ration available for milk production with No. 27 as compared with that for No. 62. Since the two rations are made up in almost exactly the same proportions between grain, hay and silage, a direct comparison can be made between the amount available for milk production for the two cows by comparing the grain.

For every pound of grain available for milk production in the ration of No. 62 there was 2.64 pounds in the ration of No. 27.

The ratio between the milk produced by the two cows as already shown was 1:2.67 and for the fat 1:2.77 which coincides remarkably close to the ratio between the feed actually used for milk production. The data then shows that after the ration of maintenance is deducted, No. 62 produces milk and fat as economically as No. 27. What feed is used for milk production by the inferior cow, No. 62, is used to as good advantage as is the case with the heavy producer. The difference in economy of production arises from the fact that the former requires the greater part of what she can digest to supply maintenance while with the heavy producer a large amount is used after maintenance is provided for. This comparison is illustrated below by expressing the portions of the ration used for maintenance and for milk production in per cent.

	Used for Maintenance.	Used for Milk Production.
No. 27	35.0 per cent	65.0 per cent
No. 62	55.8 per cent	44.2 per cent

Additional Data from Cows No. 4 and No. 63.—Fortunately we are able at this point to use data secured in carrying on another line of investigation, which was under way at the same time as the one heretofore described. It has already been stated that after deducting the ration of maintenance, No. 62 produced milk as economically as did No. 27 that produced more than twice as much. The object in introducing this additional data is to determine whether or not the same is true regarding other cows than the two used in the investigation and to compare the results from No. 62 and No. 27 with these other cows. The two cows that supply this additional data are No. 4 and No. 63.

These two cows are registered Jerseys and half sisters of No. 27 and No. 62. While they were used in another investigation they were fed practically the same as were the two animals which furnished the data heretofore given. No. 4 and No. 63 calved at almost the same time and were fed on the same ration as No. 27 and No. 62 with the exception that the proportion between the grain and hay was not kept entirely uniform. They were fed from the same mixture of grain at all times as was used for feeding No. 27 and No. 62, and all were fed from the same hay and silage. Furthermore, they were kept farrow during the year and were kept at uniform weight in exactly the same way as was done with No. 27 and No. 62. At the end of twelve months they were both dried up and were then kept on maintenance on the identical ration used for No. 27 and No. 62. With No. 4 the maintenance period covered 150 days and with No. 63, 120 days. Further and complete details regarding the feeding of these animals during the

year they were producing milk and during the period of maintenance will be published later. At this time only the summaries are given which are necessary in order to study the question under consideration.

Table 17 gives a summary of the feed consumed by these two animals during the year.

TABLE 17.

SUMMARY OF FEED FOR YEAR.

No. 4 and No. 63.

No.	Grain.	Alfalfa Hay.	Silage.	Green Feed.
4	3035.3	3376.0	7034.3	2490.1
63	2968.0	3298.0	8046.7	2501.3

TABLE 18.

COMPOSITION AND YIELD OF MILK AND MILK CONSTITUENTS.

No. 4 and No. 63.

No. Cow.	Days in Milk.	Yield Milk.	Fat.		Protein.		Sugar.		Ash.	
			%	Yield.	%	Yield.	%	Yield.	%	Yield.
4	365	6773.6	5.50	372.9	4.12	278.3	4.28	290.2	.77	51.4
63	365	6033.9	6.09	367.9	4.37	263.8	4.21	254.3	.72	44.9

The proportion between the grain, hay and silage is much the same as was fed No. 27 and No. 62. Table 18 gives a summary of the yield of milk, its composition, and the total yield of milk constituents for the two animals. It will be observed that the two animals produced very near the same amount of milk but the milk of No. 63 contained on the average .59 per cent more fat. These two animals ranked between No. 27 and No. 62 in yield of both milk and fat. Tables 19 and 20 give a summary of the food consumed on maintenance by the two animals.

TABLE 19.

SUMMARY OF FOOD CONSUMED ON MAINTENANCE BY NO. 4.

	Grain.	Alfalfa Hay.	Silage.	Average Weight.
150 days	513.9	514	2066.4	792
Average per day	3.43	3.43	13.78	...

TABLE 20.

SUMMARY OF FOOD CONSUMED ON MAINTENANCE BY NO. 63.

	Grain.	Alfalfa Hay.	Silage.	Average Weight.
120 days	353.4	353.4	1425.6	888
Average per day	2.95	2.95	11.88	...

These figures show that there is a difference in maintenance requirements in this case as was found with the other two animals, No. 4 requiring 3.43 pounds grain on the average to 2.95 pounds required by No. 63, the other parts of the ration being in the proportions. At the same time No. 63 weighed almost 100 pounds more. If we were to calculate the maintenance on a basis of 1000 pounds live weight, this variation would be still more marked. Tables 21 and 22 give the amount of feed available for milk production during the year the two cows were in milk. This is found as described for Tables 15 and 16 by subtracting the maintenance required for the entire year, calculated at the same rate as actually determined for short periods, from the total feed consumed during the year when milk is being produced.

TABLE 21.

FEED AVAILABLE FOR MILK PRODUCTION DURING 1 YEAR IN MILK.

No. 4.

	Grain.	Alfalfa Hay.	Silage.	Green Feed.
Feed consumed 1 year in milk	3035.3	3376.0	7034.3	2490.1
Maintenance for year	1251.9	1251.9	5029.7	......
Available for milk production	1783.4	2124.1	2004.6	2490.1

TABLE 22.

FEED AVAILABLE FOR MILK PRODUCTION DURING 1 YEAR IN MILK.

No. 63.

	Grain.	Alfalfa Hay.	Silage.	Green Feed.
Feed consumed 1 year in milk	2968.0	3298.0	8046.7	2501.3
Maintenance for year	1076.7	1076.7	4336.0	......
Available for milk production	1891.3	1221.3	3710.7	2501.3

The ration consumed by No. 63 was somewhat different in proportions from the others and in order to compare the relative amount of hay, grain, silage, and green feed consumed in the rations of the four cows the following summary is made:

RATIO BETWEEN CONSTITUENTS OF THE RATION WITH THE FOUR COWS.

	Grain.	Alfalfa Hay.	Silage.	Green Feed.
No. 62	1	.89	2.67	1.10
No. 27	1	.85	2.56	1.26
No. 4	1	1.11	2.32	.82
No. 63	1	1.11	2.71	.84

The above shows that No. 4 and No. 63 had more hay and less green feed in proportion to the grain than was used by No. 27 and No. 62. However, the ration is not so far different in its composition. For this reason the statement below is prepared showing the ratio for the four cows between the available grain in the ration and the fat and milk produced, representing the figure for No. 62, by unity which is in each case the smallest.

COMPARISON OF FOOD AVAILABLE FOR MILK PRODUCTION ON BASIS OF GRAIN ALONE.

	No. 62.	No. 27.	No. 4.	No. 63.
Ratio grain available	1	2.64	2.12	2.25
Ratio fat produced	1	2.77	2.20	2.17
Ratio milk produced	1	2.67	2.12	1.89

The close agreement between the ratio of available food consumed and the fat in the milk produced has already been pointed out for No. 27 and No. 62. It will be seen from the statement above

that with No. 4 it is correspondingly close while with No. 63 there is more variation. However, No. 63, as already shown, was given a ration varying considerably in the proportions between the grain and hay from that given the other animals, and furthermore her milk was considerably richer in fat than was the case with that produced by the other cows. These facts, are sufficient to account for the ratio being wider between the grain of this cow and No. 62 than is the ratio between the milk and fat.

Since these rations varied in composition as shown and the milk varied in composition as well, the following calculations are introduced, where by expressing both the value of the feeds in the ration, and the value of the solids in the milk in calories, it is possible to reduce both to a basis that admits of a fair comparison. In making these calculations the "production value" as given by Dr. H. P. Armsby, Bulletin 71 (Revised Edition), Pennsylvania Experiment Station, was used. Table 23 gives the value in calories for the average daily ration consumed by the four cows while in milk. Table 24 gives the value in calories of the average daily ration for the four cows while on maintenance. Table 25 gives the value of the milk solids computed in calories. In preparing this table the following values for the milk solids were used.*

Milk protein	Calories per gram	5.86
Butter Fat	Calories per gram	9.23
Milk Sugar	Calories per gram	3.95

The figures for the total yield of the several milk constituents will be found in Tables 10 and 11 for No. 27 and No. 62, and in Table 18 for No. 4 and No. 63.

*Hammarsten, Physiological Chemistry, p. 625.

TABLE 23.

PRODUCTION VALUE IN CALORIES.

(Average Daily Ration in Milk.)

Nos. 27, 62, 4, 63.

		No. 27.		No. 62.		No. 4.		No. 63.	
	Calories Per Lb.	Lbs.	Total Calories.	Lbs.	Total Calories.	Lbs.	Total Calories.	Lbs.	Total Calories.
Corn	888.5	5.4	4797.9	3	2665.5	4.8	4264.8	4.7	4176.0
Bran	482.3	2.7	1302.2	1.5	723.5	2.4	1157.5	2.3	1109.3
Oilmeal	789.3	1.3	1026.1	.8	631.4	1.2	947.2	1.2	947.2
Alfalfa Hay ..	344.1	8.0	2752.8	4.7	1617.3	9.3	3200.1	9.0	3097.0
Silage	142.6	24.1	3436.7	13.9	1982.1	19.3	2752.2	22.1	3151.5
Green Alfalfa	108.1	6.6	713.5	3.5	378.4	3.6	389.2	3.6	389.2
Green Corn ...	110.2	5.3	584.1	2.2	242.4	3.3	363.7	3.2	352.6
Total			14,613		8,240.		13,074.		13,222.

TABLE 24.

PRODUCTION VALUE IN CALORIES.

(Average Daily Ration on Maintenance.)

Nos. 27, 62, 4, 63.

		No. 27.		No. 62.		No. 4.		No. 63.	
	Calories per Lb.	Lbs. Fed.	Total Calories.	Lbs. Fed.	Total Calories.	Lbs. Fed.	Total Calories.	Lbs. Fed.	Total Calories.
Corn	888.5	1.9	1688.2	1.7	1410.5	2.0	1777.0	1.7	1510.5
Bran	482.3	.9	434.1	.8	385.8	1.0	482.3	.8	385.8
Oilmeal	789.3	.5	394.7	.4	315.7	.5	394.7	.4	315.7
Alfalfa Hay	344.1	3.3	1135.5	2.9	997.9	3.4	1169.9	2.9	997.9
Silage	142.6	13.2	1882.3	11.8	1682.7	13.8	1967.9	11.9	1696.9
Total			5,534.		4,792.		5,791.		4,906.8

TABLE 25.

VALUE OF MILK IN CALORIES.

(Weights in Pounds.)

	Value per Lb. in Calories.	No. 27.		No. 62.		No. 4.		No. 68.	
		Amount Produced.	Total Calories.	Amount Produced.	Total Calories.	Amount Produced.	Total Calories.	Amount Produced.	Total Calories.
Fat.	4190.4	469.9	1969069.0	169.3	709434.7	372.9	1562600.2	367.9	1541648.2
Protein	2660.0	339.3	90253.8	127.2	33835.2	278.3	74027.8	263.8	70170.8
Sugar	1793.3	392.4	703690.9	144.3	258773.2	290.2	520415.7	254.3	456036.2
Total .. .			2,763,014.		1,002,043.		2,157,044.		2,067,855.

Table 26 gives a summary of Tables 23 and 24 and in addition shows the total calories per day available for milk production by each cow after the maintenance requirement is supplied. The ratio is then given between the available calories in the daily ration of the four animals while producing milk, and the ratio between the milk solids expressed in calories counting the production of No. 62 as unity in both cases.

TABLE 26.

SUMMARY OF CALORIES IN DAILY RATION, IN MILK AND ON MAINTENANCE; AND RATIO BETWEEN AVAILABLE CALORIES IN FEED AND IN MILK SOLIDS.

	No. 62.	No. 27.	No. 4.	No. 63.
Total Calories in average daily ration in milk	8241	14614	13075	13223
Total Calories in average daily ration on maintenance	4793	5535	5792	4907
Total Calories per day available for milk production	3448	9079	7283	8316
Ratio of available Calories, No. 62 counted as unity..	1	2.63	2.11	2.41
Ratio of Calories in milk produced, No. 62 counted as unity	1	2.75	2.14	2.06

It will be seen from Table 26 that the ratio between the value of the available feed in calories and between the milk solids expressed in calories is close in every case. This shows that after the maintenance requirement is supplied one used food as economically as another for milk production. What was found to be true as between No. 27 and No. 62 by comparing their rations directly by pounds fed, is found to be true as well for the four cows when the feed and milk product is expressed in calories.

Here we have four animals kept under identical conditions except a slight variation in the proportion between the grain and hay, all kept at uniform weight during the milking period and all kept farrow. We find that while there is some small difference in the maintenance requirements of the four animals, that after we subtract the maintenance from the total consumed that the ratio of their production is practically that of the available food. It seems to the writer that the evidence furnished by these four animals is so consistent that it is entirely safe to draw a general conclusion that as between these

dairy cows at least and probably between others the difference in the economy of production is dependent upon the amount of food which they can consume and use above the ration of maintenance.

Results of Feeding No. 62 to the Limit of Her Appetite.—In studying the results of the experiment reported with the two cows one question that will naturally rise is this: What would have been the result had No. 62 been fed all the feed she would consume, in place of her ration being regulated by her live weight? It was concluded from observation that she would have taken somewhat more feed than she received during that part of the milking period when producing the maximum quantity, but she had at no time appeared hungry, and it was evident that she was almost to the limit of her capacity for food. Practical experience would indicate that she would not have produced more than a small additional amount of milk no matter how she was fed. At the same time the question remained unanswered as to what would have resulted had she been given all the feed she would have consumed.

The maintenance test already reported ended February 26, 1909. She was bred shortly after this and calved November 30, 1909. She was then put on a ration practically the same as given two years before while the data heretofore presented was being gathered. She was at first fed what would be considered a normal ration to support the amount of milk produced. In this milking period for the first few weeks she produced from 4 to 5 pounds more milk per day than ever before. This, however, could not be attributed in any way to a difference in the feed since she was fed practically the same ration as given before. It is not unusual for such variations to occur from one year to another in the amount of milk produced by the same animal due to conditions which cannot be determined.

Beginning with December 22nd the ration fed was gradually increased above the normal requirements for a cow producing that quantity of milk. By January 12 the ration was raised to 11 pounds grain per day and by the end of January to 13 pounds per day. As the grain ration was increased the consumption of hay and silage was decreased as will be seen from the data given in Table 27. As the grain was increased she refused the silage first and for that reason silage was dropped from the ration during the last period, February 10 to 19. From December 22 to February 19 she was fed all the feed it was possible to get her to consume. The result shows that her capacity for using food was but very little above the ration fed during the experimental milking period as reported in Table 5. It will be noted from Table 27 that there was no increase in the amount of milk as the feed was increased. More milk, in fact, was produced when she received

8.4 pounds grain a day than was produced when she received 14.8 pounds grain per day. This proves that the small production of milk by this cow in the experimental period did not result from an insufficient ration. During the 70 days covered by the data presented in Table 27 the extra nutrients consumed above that necessary to provide for the milk was evidently used in depositing fat on the body as there was a gain in weight of 25 pounds in 70 days.

TABLE 27.

RECORD OF FEED CONSUMED AND MILK PRODUCED.

No. 62.

Period.	Date.	Lbs. Grain.	Lbs. Alfalfa Hay.	Lbs. Silage.	Value Daily Ration in Calories.	Total Lbs. Milk.	Average % Fat.	Average Weight.
2	12-12—12-21	59	78.5	150.0	9307	185.6		877
3	12-22—12-31	84	103.4	72.5	10961	190.7	5.4	875
4	1- 1— 1-10	93	91.0	108.5	11729	193.8	5.0	893
5	1-11— 1-20	112	87.0	74.3	12546	203.4	4.7	892
6	1-21— 1-30	130	79.4	75.3	13666	192.5	4.6	889
7	1-31— 2- 9	145	106.7	59.8	15581	189.0	4.6	902
8	2-10— 2-19	148.2	111.0		15059	187.2	3.6	902

In addition to its bearing upon the problem under consideration, the results have an important bearing on the problem of feeding. They show with this animal, what is unquestionably a general rule; that when a sufficient amount of feed is given to support milk production to the full capacity of an animal, that additional feed will not bring greater results. If the animal has not the stimulation, whatever it may be, necessary to produce milk it cannot be brought about by an increase in the ration.

SUMMARY AND CONCLUSIONS.

During the first two lactation periods the better of the two Jersey cows in this investigation produced 2.8 pounds of milk and 3.9 pounds of fat for each pound produced by her half-sister. The object of this investigation was to determine the cause of this wide variation with these two cows, anticipating that an explanation as between these two cows would explain the cause of variation with dairy cows in general.

In the third lactation period the two cows calved three days apart and were kept under the following conditions:

The two were fed a ration of exactly the same composition.

The quantity was so regulated as to maintain a uniform weight.

Both cows were kept farrow.

Complete records were kept, and analysis made, of feed consumed and milk produced for the entire lactation period.

A ten-day digestion trial was carried out while the two cows were in milk.

A maintenance trial was conducted at the end of the milking period.

During the year of the investigation No. 27, the better cow, produced 8522 pounds of milk and 469.9 pounds of fat; No. 62 produced 3188 pounds of milk and 169.3 pounds of fat. No. 27 produced 2.67 pounds milk, and 2.77 pounds fat for each pound produced by No. 62.

No. 27 consumed 1.75 pounds of feed for each pound used by No. 62.

The maintenance trial showed only a slight difference in cost of maintenance, the higher requirement being with No. 27.

The digestion trial showed practically identical results. The co-efficient of digestion for No. 27 was 64.39 per cent and for No. 62, 64.99 per cent.

The real cause of the difference in production was found to be in the amount of feed consumed above maintenance.

No. 27 used 35 per cent of the total food consumed, and No. 62, 55.8 per cent for maintenance.

After deducting the maintenance requirement one cow produced milk as economically as the other.

Data is presented of two other cows kept for an entire lactation period under identical conditions as those above described.

The amount of food required for maintenance during the year is estimated for each cow individually from a trial covering a period of from 120 to 180 days.

The feed consumed during the lactation year minus the estimated maintenance is the amount considered available for milk production.

The ratio between the food available for milk production and the milk produced is practically the same with each of the four cows.

The available feed consumed and the milk solids produced are also calculated in calories in order to reduce all to a common basis.

The ratio between the calories available for milk production with the four cows agrees closely with the ratio between the calories in the milk solids produced by the same animals.

This shows that with the four cows, as for the two made the special object of this investigation, the cause of the difference in the amount of milk produced is the amount of food they are able to consume and use above that required for maintenance.

The main difference between profitable and unprofitable dairy cows is not to be found in the coefficient of digestion, or in the amount of food required for maintenance.

A superior dairy cow is simply one with a large capacity for using food above the maintenance requirement and one that uses this available food for milk production.

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UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

Soils of The Ozark Region

A Preliminary Report on the General Character of the Soils and the Agriculture of the Missouri Ozarks

BY C. F. MARBUT, PROFESSOR OF GEOLOGY,
UNIVERSITY OF MISSOURI

COLUMBIA, MISSOURI
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[1] In the service of the U. S. Department of Agriculture.

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SOILS OF THE OZARK REGION.

BY C. F. MARBUT.

INTRODUCTION.

This report is an attempt to determine the character, distribution, and natural fertility of the soils of the Ozark region as well as to suggest, in the light of the results of this study, the most profitable way of handling them. It is an attempt to direct attention to the proper channels and to find the best means of making the region yield a larger income. The results so far attained cannot be considered absolutely final but it is confidently believed that data have been already obtained upon which suggestions of considerable value to the farmers of the region may be based.

It is not a detailed report and does not therefore deal with all of the types of soil existing in that large area of country. The conclusions drawn concerning the soils, and the systems of agriculture adapted to them, are general only. It is merely a preliminary report and will be followed by detailed study as rapidly as the circumstances will permit.

Soil investigation in the region has long been needed. A large part of the area has a soil of only moderate fertility and therefore a soil that will not stand abuse indefinitely. It does not smile upon the farmer who refuses to treat it well and to supply it with food. It does not lavish great wealth on the soil robber simply because it has not the great wealth to expend upon him. On the other hand it is of such a character that it will not refuse to reward to the fullest extent the hand that feeds it. Its response to good treatment is prompt and full. It returns to the farmer products of many times more value than the value of the food that he gives it.

The Ozark farmer, however, has not learned to treat his soil like he treats his horse. He is unable to hear the cry of the starved soil as he hears that of his live stock, though the value of the response of the soil to good treatment is probably greater than that of live stock. The latter can move about from place to place and often gain sustenance regardless of treatment by the owner, the former cannot do so.

The roughness of the country and the occurrence of mineral deposits of considerable value in parts of it have caused the people to turn a great deal of their attention to mining, neglecting their farms. The land has become poor in proportion to this neglect.

Agriculture, including Animal Husbandry, is the only permanent industry to which the Ozark region as a whole is adapted. There is a great deal of the region that can never, or probably will never, be converted into tillable land, yet for the region as a whole agriculture will become its most important industry. That part of it not adapted to agriculture will be utilized for growing timber.

The first few pages of the report deal with the reasons for having a soil survey. This is followed by a short description of the geography and geology of the Missouri Ozark region with chief stress laid upon the character and distribution of the different beds of rock that appear on the surface in the different parts of the region. This is followed by a short general description of the soils as a whole, after which the soils are subdivided into groups and each group described in terms of the character of rock from which it has been derived, its distribution, topography, timber growth, area in cultivation, and physical and chemical characters of the soil. The description of the soil groups makes up the greater part of the report. The agricultural conditions of the region are described in general terms including a short history of its agricultural development. It is shown that for the central part of the region the average farmer probably receives less income now than he received forty years ago. This is due to the decrease in the size of the bottom land farms resulting from subdivision, and to the destruction of the native grass by the growth of brush and timber. This latter condition is the result which has arisen because of the fencing up of a small part of the upland and the consequent stopping of the annual prairie and woods fires. It may be due in a few cases, also, to over grazing.

The fruit industry is considered briefly and the conclusion is reached that it can never constitute the great fundamental industry of the region. That must be stock raising and dairying. The land must be reset in grass.

THE REASONS FOR A SOIL SURVEY.

Modern society recognizes the intimate relations existing between the prosperity and happiness of mankind and the resources of the earth's crust. These resources constitute the raw material from which man obtains the supplies to satisfy his many and varied requirements. It is upon these that the very existence of man depends, and upon their continued abundance and availability depends all future progress.

The duration of the life of the human individual is short. He depends upon the resources of the earth's crust, at most, but a few years. He is directly concerned with the present and the immediate future, and ordinarily thinks or cares little about the distant future

of the world. Human society in some form is, on the other hand, perpetual. It neither begins nor ends with the life or death of an individual or group of individuals. It is as much concerned with the distant future as is the individual with the immediate future. It must or should plan for all time.

If the resources of the earth's crust were inexhaustible there would be no occasion whatever for spending any time, thought or energy upon them in any way. It has long since been demonstrated, however, that under the conditions produced by the occupation of earth by a dense population of human beings the resources are not inexhaustible. That although none of these resources can be absolutely annihilated, yet they are being rapidly placed by man in positions where they are not easily available.

It is incumbent upon society, therefore, in order to plan intelligently for the future, to determine the nature, amount and availability of these resources. Every government, as the personification of a particular portion of human society, should determine these things within the area of its jurisdiction.

It was not until the 19th century had been well advanced that man began to realize these things to such an extent that any action was taken. Such action at first related only to the so-called mineral resources—those that are secured by mining. It is now a well recognized duty of the government of every civilized nation to determine the nature, amount and availability of its mineral resources. Every civilized government has well organized departments devoted to this work and a great body of men have been specially trained for it. In the United States this work has been vigorously prosecuted for nearly half a century by a strong central organization of the national government and by many efficient state organizations. Up to the closing years of the 19th century very little interest was manifested, especially by the American people, in the greatest of all the earth's natural resources: the soil. Great sums of money were spent on the investigations of mineral deposits as well as upon the various subsidiary industries that depend upon the soil as a foundation, such as animal husbandry, plant breeding and fruit growing, etc. Yet practically nothing was done toward determining the source of the soils fertility, the reserve store of it in the soil, its rate of consumption or the geographic distribution of the various soils of the country. Volumes had been written on growing and feeding crops, on breeding and care of animals and even on the treatment and improvement of the soil before a clear idea had been gained of what the soil is, what constitutes its crop producing capacity, or what, in any particular case, is its store of fertility. Mineral maps, geological maps, timber maps, crop maps

and live stock maps have long been familiar articles of use to intelligent men, yet soil maps are even yet almost a curiosity. The study of the soil is not a recognized function of geological or mineralogical surveys. The attention that this work has been receiving during the last few years is due to the work of the United States Department of Agriculture and to the Agricultural Experiment Stations of the various States. They have originated the work, and in many states the stations are engaged in a more or less systematic investigation of the soils of the state in which they are located, while the work of the Bureau of Soils of the National Department of Agriculture undertakes to extend such work over the whole country. The attitude of the Experiment Stations arose naturally as one of the conditions for the improvement of agriculture.

As long as mining was unsystematic and intermittent; as long as large areas of the earth were unoccupied and the surplus population had an easy outlet to new and unexplored country and until modern industrial conditions produced a great demand for the products of mines, no attention was paid to the total supply of the minerals of the earth. It was assumed that the earth contained an abundance and much to spare. As long, likewise, as agriculture was a rule of the thumb and as long as the farmer could get a new farm of virgin soil as fast as an old one was worn out there was little thought or attention paid to the soil. With the exhaustion of the free public land in the United States and the change to an intensive agriculture due to high-priced land and a denser population there came a demand for an accurate knowledge of the soil and of the means of improving it.

In a modern mining industry in which the speculative element has been eliminated one of the first things to be determined, if possible, is the amount of ore or other product that can be made available on the property. On this and the quality of the material will depend to a great extent the plan of operation of the industry. The property is thoroughly prospected, the size, shape and quality of the ore body determined and the future of the industry planned accordingly.

Mining, however, is a temporary industry. It can exist in any particular locality only so long as there is some valuable product to mine. Agriculture on the other hand is a permanent industry. It must exist as long as human society. It is now and has long been recognized by thinking men that the soil, the fundamental basis of agricultural industry, must be looked upon somewhat in the same way as a deposit of mineral. The plant food in the soil corresponds to the ore in a mineral deposit. The growing of crops is the farmer's method of mining the valuable material out of the soil. A part of the plant

food consists of minerals, and like all other mineral deposits, they exist in the soil in a definite quantity. The soil in this sense is, therefore, a mineral deposit which is being mined out by the peculiar mining method of the farmer.

Since agriculture must be permanent, however, the great problem is to devise a method by which the soil may be maintained in a permanently fertile condition in the cheapest possible way. The growing of crops is, however, more than a mere method of mining the fertility from the soil. It is a method of mining and manufacturing in one act, extracting the fertility from the soil and at the same time manufacturing it into products of much greater value than that of the unmanufactured elements, the raw material. The maintenance of the fertility depends upon the return to the soil in a cheap form of the elements taken from it and used by the plant in the making of the various products which we call crops. The amount and kind of the materials to be put into the soil can be determined accurately only through an intimate knowledge of what the soil has to start with, what its facilities are for holding them and delivering them up at the proper time and in the proper condition for the plant as well as what is being taken out by the crop. A knowledge of both these things is necessary; one equally so with the other. The former knowledge can be gained only by a study of the soil in the field and such a study of the soil in the field and laboratory is the legitimate function of a Soil Survey.

The other elements of fertility in the soil in addition to the mineral elements are not to be neglected. All the elements and conditions of fertility are important as objects of study. They are the objects of research as well as the mineral elements. The final limit of agricultural permanence and production will probably, in the end, be determined by the mineral fertility since this cannot be produced in the soil, and the total available quantity is small. If the soil is robbed of it, it must be carted back and replaced from some outside source. One of the main functions of the field division of a soil survey, therefore, in addition to determining the location of the different soils, is to determine the physical character and mineral content of the soil.

If society is sufficiently interested in the minable mineral deposits of a country to be willing to tax itself for the purpose of determining their probable quantity and quality, to a much greater degree should it demand the investigation of the soils on which its very existence depends. The mining industry of any region is temporary and recognized as such while agriculture is as permanent as society itself.

THE MISSOURI SOIL SURVEY.

The Missouri soil survey was organized by the Missouri Agricultural Experiment Station in the spring of 1905. Its work was grouped under two heads; (I) The soil survey proper, including the determination of the field character and relations of the soils as well as their study in the chemical and physical laboratory; (II) the experimental study of certain types of soils by means of crop growing under greatly varying conditions. The several parts of the work were placed under the direction of the professors of the Agricultural College most directly concerned. The survey proper was placed under the direction of the Professor of Geology and the Crop Experiment work under the direction of the Professor of Agronomy.

Three seasons of three months each have been spent in the field. In addition to a great deal of data concerning the crop experiments and the chemical characters of many samples of soil all of which will be discussed later, reconnoissance work has been carried over the greater part of southern Missouri. A general examination of the main soil groups of the Ozark region has been made. The soils have been broadly classified, samples have been collected and analyzed and the results are shown in the soil map accompanying this report. Each kind of soil is described as to origin, character, distribution and general fertility in the first part of this report. The general agricultural conditions obtaining in the region are discussed in the second part.

THE OZARK REGION.

Location.

The Ozark region as a whole is an oval shaped area lying chiefly in southern Missouri and northern Arkansas. It extends a short distance into Oklahoma on the west and into Illinois on the east. A little less than half of the total area lies within the state of Missouri.

Boundaries.

The boundaries, if run exactly, would be very irregular, extending outward along every stream flowing out of the region and inward along every ridge. There is no universally recognized criterion or body of criteria for determining its boundary. Everyone recognizes the rather rough region of south central Missouri with its stony red or gray soils as the Ozark region but the change from the rough country

of the Ozark interior to the smoother country of the prairies to the north and west is gradual. The soils of the Ozark region are not all stony and some soils outside of the region have reddish and brownish and yellowish colors. The most striking and most persistent feature characterizing the Ozark region, especially in Missouri, and differentiating it from the surrounding areas, is the practically universal occurrence in it of limestone. Limestone is the Ozark rock, so far as Missouri is concerned, *par excellence*. A few thin sandstone beds occur in it but they merely give a local character to the relatively small area in which they occur. The Ozark region is the region, in Missouri, of massive limestones. Its boundary is the line or belt between the country where limestone is the predominant rock and that where shale or sandstone or clay predominates. The northern boundary, from St. Charles to Arrow Rock, lies along the northern part of the hilly belt bounding the Missouri river valley on the north. Thence southwestward for a long distance, the boundary is not a sharp line. There is a rather gradual change on this side from the smooth or rolling prairies with their broad flat-bottomed shallow valleys to the rougher Ozark region with its narrow and often deep valleys. This indefiniteness is especially characteristic of the stretch from Arrow Rock to the Osage river at Taberville. It is less sharp on the uplands than on the streams. In fact the place where the boundary crosses the streams is usually easily located as the place where the valleys become narrow and where limestone and flint rock appear in the creek and river cliffs. From Arrow Rock the line runs southward crossing Salt Fork in the neighborhood of Blackwater. It then follows up Lamine river and Big Muddy creek to the neighborhood of the bridge over which the Lexington Branch of the Missouri Pacific railway crosses the latter stream. Thence it swings eastward around the edge of the Sedalia prairie crossing Flat Creek east of Green Ridge. It runs thence eastward to the Meridian of Cole Camp, and then, in general, westward to Tebo Creek ten miles below Calhoun. Thence southward, with an eastward loop around the Sandy prairie west of Leesville, crossing Grand river at Brownington and the Osage at Taberville, running eastward or southward on the ridges and northward or westward in the valleys. South of this it crosses Horse Creek not far from the west line of Cedar county with a deflection to the eastward on both sides of it, running south through Stockton. From that place it runs in a nearly direct line to Golden City and Jasper. Beyond this, it follows approximately the valley of Spring river. The other boundaries, except that from St. Charles to the Mississippi river in the southern part of the city of St. Louis, and that from Cape

Girardeau to the state line south of Doniphan in Ripley county, lie outside the state.

General Character.

Of the 70,000 square miles in the area of the state about 30,000 are included within the boundaries of the Ozark region. An area including as large a proportion of the state as this will be an important factor in the state's industries. Its rate of progress or its industrial condition will profoundly affect the whole state in this and other respects. The estimation in which it is held as a favorable or unfavorable region for human exploitation and habitation will determine to a considerable extent the standing of the state.

The estimation of the value of a region for agricultural purposes depends greatly upon a comparison with the country surrounding it. The prairies lying north and west of the Ozark region are noted for their fertility. Their topography and climate also are favorable, in the highest degree, to an intense and profitable agriculture. They possess all the favorable conditions to an extraordinary degree; to a greater degree probably than any other area of equal size in the world.

The Ozark region on the other hand has, as a rule, a rather uneven surface; it is covered with timber or brush necessitating considerable expense in preparing the land for the plow; its soil is usually stony, making cultivation rather difficult and costly, and while its soil is not sterile as a rule yet it is less fertile than that of the surrounding region. Its climate is essentially the same as that of the surrounding areas in corresponding latitudes. In comparison, therefore, the region has some disadvantages.

As long as large bodies of fertile prairie land lay open for settlement or could be bought cheap, men were unwilling to do the work necessary to clear the stony timbered lands of the Ozark region. This has not only retarded its settlement but has kept the capital necessary for rapid and effective development out of the country.

The region as a whole is rough. Its streams all flow in valleys which usually are rather deep, narrow and steep-sided. Its roughness is, however, not so great as is ascribed to it by the popular idea. The popular misconception concerning the region is due to two causes. One of them, and probably the chief one, is the name that was early applied to it and which has remained attached to it even in the face of a clearer knowledge of the facts. The expression "Ozark Mountains" seen in print and placed on the maps in the old geographies has produced an impression that will be long in disappearing. This applies chiefly to the public as a whole who have not seen the region.

Another reason for the misapprehension is its contrast with the surrounding country and to a considerable extent a contrast that does not concern the shape of the surface directly. The effect produced by its cover of timber and the contrast between its timber and the surrounding prairies has had a great deal to do with the popular idea of its roughness.

The impression produced by the great abundance of stones occurring everywhere on the surface has had its influence in the same direction also. Considerable areas of it are smoother than much of the best parts of northern Missouri. On the other hand, large areas of the region are rougher than any part of northern Missouri. The rough regions lie in the neighborhood of the large streams while the smooth areas are along the watersheds.

The roughness of the region, however, is invariably of a broader, less intricate and less minute type than that of the northern part of the state. In both regions the roughness is due to the erosion of valleys in a nearly level surface. In the northern part of the state many of the hilly areas along the streams are so intricately eroded, so minutely cut up with the steep hollows and ravines that it is impossible to do anything with the land except convert it into pasture. In south Missouri, on the other hand, the minute drainage lines are less abundant; the slopes are therefore broader and smoother, and are capable of cultivation as well as conversion into pasture.

The soil and topography of the region are the direct result and its covering of timber an indirect result of the character of the rocks that lie under it. If the same kind of rocks lay under the Ozark region as those lying under western Missouri and eastern Kansas, its surface would be the same as in those areas. The boundaries of the region are determined by the extent of the rock which gives it its characteristics. In this respect the boundary is geological. It is geographic also since the geology (rock) determines the character of the soil and the shape of the surface. The Ozark region in Missouri is, as a whole, a limestone region. With the exception of the relatively small granite and porphyry area of the eastern part of the Ozarks and other small areas with sandstone and shale, limestone is universal. It is exposed in every river and creek bluff and encountered in every well and drill hole that penetrates the solid rock. There are several different kinds of limestone ranging from pure to impure, flinty to flint-free, crystalline to earthy. The different kinds are of widely different ages also and each kind produces a different kind of soil.

Geology.

Age of the Rocks.

All the true Ozarkian rocks are of great age—all older than the age of the coal deposits of the world and most of them much older. The oldest of these rocks are as old as the oldest rocks found in any part of the United States. They are so old that it might be said that their origin dates back to a period before the beginning of legible geological history.

The youngest of the Ozarkian rocks belongs to the age immediately preceding the coal· So far as our purposes are concerned, however, the age of the rocks of the region is of much less importance than is their character. It is rock character which determines soil character.

The Kinds of Rocks.

The rocks from which the soils of the Ozark country have been made by nature's agents of disintegration belong to two of the great rock groups of the earth's crust, i. e., massive rocks and bedded rocks. The massive rocks have supplied only a very small area of the soils of the region, not more than one third of one per cent of the total area. Their effect therefore on the soil of the state is almost negligible. Although the area where they come within the reach of soil-forming agents is small this does not represent their total extent beneath the surface of Missouri. In fact they lie beneath it all but so far beneath that they are rarely reached in our deepest drill holes. They are the foundation on which the superstructure of the state has been built. The superstructure has been worn away in a few places in the granite region of the eastern Ozarks exposing the foundation to the disintegrating agencies.

On top of this foundation was laid a great thickness of rock beds built or laid one on top of another. These beds or layers are chiefly made up of limestones as stated above and where they have been worn off least their total thickness is more than two thousand feet.

These layers of rock were laid down as great sheets of material on the bottom of a sea that extended far beyond the existing limits of the Ozark region. The successive sheets were piled one on top of another and they all lay originally sensibly horizontal. The youngest layer, or the one laid down last, lay on top and the oldest on the bottom.

The successive layers included not only the limestone layers that make up the Ozark region as we know it at the present time, but

a great thickness of layers of mud, sand, limestone and coal beds that were laid on top of the limestone. The total thickness of the whole series from the granite foundation below to the top of the sands, clays and coals of the coal measures was at least 3000 feet.

Structure.

After this series of layers had been spread out one on top of another on the bottom of a sea that included the whole of the Mississippi basin and probably much more, the whole region was raised above the sea. Where the Ozark region now lies these layers were not only raised above the sea with the rest but they were bowed upward into a low, broad, gently sloping ridge, standing higher therefore than the newly uplifted land of the surrounding country. These successive changes are graphically shown in plate I. The upper series of three sections represents the lay of the rock beds along the line A, B, C, D (see the small sketch map accompanying it) as they were before they were bowed upward. The middle series of three sections represents the same beds after the upbowing. The crooked black line drawn across these beds nearly horizontal is drawn approximately where the present surface of the region lies in this series of beds. The lower series of three sections is a more accurate representation of the surface as it is at the present time. It shows also the relation of these to the various soil belts crossed by the section.

The center or highest point, immediately after the upbowing, was not exactly in the geographical center of the Ozark region but was east of this, in the Iron county region. It was only in the Ozark region that these beds were bowed up. Elsewhere they retained the same attitude that they had from the first.

Erosion.

The upbowing in what is now the Ozark region exposed the top of the upbowed part to more vigorous wear by the elements than the lower country around it. The top layers were worn off in that part that had been raised up higher than the surrounding country. The layers of sand, mud, clay and coal from the upbowed region were worn away exposing the limestone layers beneath them but left the former layers still overlying the latter in the lower country around the region. The wearing not only took off the upper layers but took off all of the layers of the limestones from the central part or the part that was bowed up the highest, and much of them from most of the rest of the area. The top limestone layer was removed from the largest area and the lower ones from successively smaller areas. In a small area around the Iron Mountain country in southeastern Missouri all the limestone layers were worn off exposing the old foun-

dation on which the whole series had been laid. What we now call the Ozark region in Missouri is the country where the limestone beds have been uncovered, including also the small area from which all the layers of limestone have been removed.

This wearing process finally produced a nearly level plain, which extended over the whole Ozark region and which has, since it was formed, been cut up into valleys and ridges by the existing streams. Small remnants of that old level surface still exist in many places in the Ozark region like the high smooth country around Springfield, Rolla, Lebanon, Salem, Versailles and Owensville. Most of it, however, has been cut to pieces with valleys.

In this levelling off no one bed was wholly removed from the whole area of its original extent. None of the beds were worn off outside of the Ozark region because, as stated before, they were and still are covered by later beds. It was only in the upbowed Ozark region that they were worn away and the greatest number of the beds were cut through immediately under the highest part of the upbow. The deepest bed touched or reached by the leveling work was removed from the smallest area and the highest or top bed was removed from the largest area. This youngest layer was worn away until it has become nothing more than a rim or ring belt running around the outer edge of the region. The next lower bed makes a belt inside this one running around the region and each successive lower bed forms a ring, each one becoming smaller the nearer the center we come until we reach the center, where even the oldest layer has been removed and the granite foundation has been exposed. If nothing more had been done than merely the laying down of the successive layers of material, we should of course be able to see only the top layer; the older layers being covered by the younger ones.

Description of the Various Rock Beds.

The layers of rock, as stated above, are not all exactly alike though the most abundant rock, by far, is limestone. The bottom rock, the foundation of the original pile of layers and the one now seen in the center of the region surrounded by rings of the younger layers, is made up of igneous rocks in which granite is an important factor. All of this foundation rock has very much the same composition as granite and differs from it only in texture. So far as the soil which is produced from it is concerned it may all be called granite.

The next layer is a sandstone. It is not thick and does not underlie a broad area. It was not formed as a complete continuous layer but only in patches so it is found only in patches around the granite area. It is known as the LaMotte sandstone. Above the

LaMotte sandstone occurs a limestone known in different parts of the Ozark region as the St. Joseph, the Proctor and the Fredericktown limestone. It is several hundred feet thick, is a continuous layer and is found all around the granite and sandstone area, except where it is covered by the next higher layer. Its character varies somewhat, being a somewhat bluish shaly limestone in some places and a gray highly crystalline limestone in others. Its most important characteristic, however, is the absence from it of flint layers and nodules. A thin sandstone comes next in the series. It is known as the Gunter sandstone. It seems to have been formed in a small area. It is seen, therefore, only in a few places and is not exposed at any place over a wide area. It has had practically nothing to do with soil making in the region.

The next layer is a limestone, several hundred feet in thickness, and exposed over a wide area of country. It consists of massive beds of crystalline limestone with very little shale or shaly limestone except in a small area in southeastern Missouri. Being a thick bed, its different layers are not all alike, but their chief differences so far as their relation to the soil is concerned lie in the varying amount of flint which occurs in them. Taken as a whole this formation or layer has more flint than any other layer of the whole Ozark region. It occurs however, chiefly in the top part of the formation with a smaller quantity in the bottom part. The middle beds are almost entirely free from it and in some places the same is the case with the bottom beds. The flint may occur in thin layers of an inch or so in thickness, in nodular or roundish masses of any size up to 6 or 8 feet in diameter or in great massive or broken and recemented layers of any thickness up to 20 feet. It is known as the Gasconade limestone.

The next layer is a sandstone. It is the thickest and most widely distributed sandstone layer in the whole Ozark region. It underlies rather large areas in the central part of the region. It does not extend entirely around the central core of the region in a belt of uniform width. It is found chiefly on the western side of the central core. It is known as the Roubidoux sandstone. In the ascending series the next is the Jefferson City limestone. It is a thick one and has a wide distribution—the widest of any of the rock layers of the region. It consists of massive crystalline layers, alternating with fine grained layers, called "cotton rock," and shaly layers. As compared with the preceding limestone layer it has a rather small percentage of flint. What flint it has is scattered through the formation rather evenly from top to bottom. It occurs usually in small roundish nodules or in thin beds. Rarely does it occur in massive beds.

Above this lies another bed of sandstone which curves around the northern and eastern side of the Ozark core, instead of the western and southwestern as in the case of the Roubidoux sandstone. It is known as the Crystal City or Pacific sandstone.

Above the Pacific sandstone lie a series of rather pure limestones free from flint which form a belt of fertile soil. They include the series of beds known in Missouri as the first Magnesian limestone and the Trenton limestone. They occur now chiefly in the eastern part of the region. Their area of occurrence is chiefly in Perry and Cape Girardeau counties.

Above this lies a thin layer of shale that is more or less continuous around the western, northern and eastern parts of the region but in a belt so narrow that it is unimportant except in a small area of southwestern Missouri. It is known as the Hannibal shale.

Finally the last layer, one that is continuous around the whole Missouri part of the region, west, north, and east, is a layer of limestone. It is about 250 feet thick but in southwestern Missouri it has a wide distribution. In the other parts of its curving area its belt is not so wide. It is made up chiefly of beds of massive crystalline pure limestone with a rather large amount of flint. The latter occurs in rather small nodular masses or in thin beds. It is known as the Mississippian limestone.

This is the top layer of the Ozark region proper and the outer ring, therefore, of this series of ever-widening rings of country.

In tabular form these rocks, beginning with the highest, lie as follows:

11. Limestone, flinty, "Mississippian."
10. Shale and clay, "Hannibal Shale."
9. Limestone, not flinty, "Trenton and First Magnesian."
8. Sandstone, "Crystal City Sandstone."
7. Limestone, moderately flinty, "Jefferson City Limestone."
6. Sandstone, "Roubidoux Sandstone."
5. Limestone, very flinty, "Gasconade Limestone."
4. Sandstone, "Gunter Sandstone."
3. Limestone, not flinty, "Proctor Limestone."
2. Sandstone, "Lamotte Sandstone."
1. Granite, "St. Francis Granite."

The numbers express the order of occurrence of these beds as one passes outward from the central core of the region.

Stages in Ozark Erosion.

The geological formations in the Ozark region affect the kind of soil, as will be shown more fully below. The topography or shape,

or character of surface, has likewise an important influence on the character of the soil. The shape that the region now has is the result of the forces of erosion or wearing down forces of rain, rivers, frost, etc., acting on the bowed up pile of rock layers described above. In general, that wearing off has had two main periods of work, the first one resulting in the wearing off of the original bowed up surface down to a lower and nearly level surface. The second period has eroded the existing valleys—the river valleys, the creek valleys and the innumerable hollows—in this nearly level surface.

When the first stage or period of erosion had been completed and before the second had begun the whole region was a gently undulating plain, a smooth country considerably lower than it is at present. The highest parts of it at that time were probably not more than 600 feet above the sea. In order to bring about the present conditions in such a region it had to be raised so that its rivers could dig deep valleys into this smooth country. This has been done and the old smooth surface has been cut by valleys so thoroughly that it is difficult to realize that it ever was smooth. The valley cutting has not been equal in the number or the depth of valleys, in all parts of the region, partly because the uplift that raised the region the last time was greatest along a line running from the vicinity of Iron Mountain to the southwestern corner of the state. The deepest valleys are therefore not on this line, for the streams here are small, nor do they occur on the outer border of the region because the uplift was not so great here. They are deepest about half way between the line of greatest uplift and the border.

Small parts of the old smooth surface exist at various places, such as the regions around Salem, Rolla, Lebanon, Springfield and on the high ridges between the main rivers.

The valleys, especially the larger valleys, are not simple. By that statement is meant that they do not slope uniformly down from the high plateau to their existing bottom lands. The descent is often made in two stages. The first descent is rather steep, less so than the second, but it is a well defined drop of 50 to 150 feet. From the foot of this slope a plain extends toward the river. It is smooth except where it is cut with valleys. It varies from a few hundred yards to several miles in width. It occurs usually on both sides of the stream. It is well developed along the Gasconade river from the southeast corner of Laclede county downward. It occurs also on Big river in St. Francois county and on most of the other large streams of the Ozark plateau belt.

From the inner boundary of this bench there is another steep descent, steeper than the other, to the existing river or the bottom lands lying along it.

This descent is often precipitous. The other never is.

The inner border of the bench, next to the river, is thoroughly cut up into small valleys and hollows by streams, most of which head only a short distance back from the river, on the bench. The larger creeks, however, head back in the plateau beyond the outer boundary of the bench. These latter are the only streams that cut into the outer border of the bench since there are relatively few in number. The outer part of the bench is therefore much smoother than the inner.

The adjacent part of the high plateau, like the inner border belt of the bench, is usually quite thoroughly cut up with valleys and hollows.

There are therefore only about five essential features in the topography of the Ozark region. These are:

1. The remnants of the original plateau, produced by the leveling action of the wearing-off processes acting on the original upbowed series of rock layers.

2. The hill edges of this plateau where it borders on the belt of bench land.

3. The bench-land plains. They lie from 100 to 300 feet or even more above the existing valley floors of the streams.

4. The hilly belts along the edges of these bench-land plains and between them and the existing valleys.

5. The valley floors or flood-plains.

The old plateau may be entirely worn away from between two adjacent bench-land plains; it may exist as merely a string of knobs lying along the watershed between two adjacent bench-land plains; it may exist as a narrow but continuous ridge or it may still exist as a broad belt of high plateau.

The bench-land plains may coalesce across watersheds of adjacent river systems making a broad area, or they may be mere narrow ribbons lying along the streams but high up above the existing valleys. They may be nearly level, or may be cut up by ravines only along the edge next the present stream, or may be cut up across their entire width. In other words, they may be destroyed as plains and converted into hill belts by the ravines that have been cut down to or near the level of the existing valley floors.

The bordering hill belts may be broad or narrow, and the bottom lands along the streams may be wide or narrow. Notwithstanding these variations the topography of the Ozark region as a whole falls

into the divisions given above and in its main features, therefore, is simple.

Of the smooth areas of the Ozark region the high plateau surface is the oldest, the bench land plains are next in age and the modern valley bottoms are the youngest. The hill surfaces are continually being slowly renewed. Their surfaces being sloping surfaces the soil is being continually renewed by having the old material washed off and newly formed material exposed at the surface.

The height of the Ozark region is nowhere sufficient to have any determining effect on the growth of crops. Any crop that will grow on the prairie lands surrounding the region will grow on the highest parts of the Ozark plateau where all other factors except elevation are made the same. The kind of soil is of more influence in this regard than is the small elevation. The gravelly and stony soils are well drained, porous, easily and rapidly warmed. They dry out and warm up in the spring earlier than the soils in corresponding latitudes either to the east or west of the Ozarks.

SOILS.

Their General Character.

Soils are made up of clay, silt, sand, gravel, stones, and vegetable matter. The clay, silt, sand, gravel and stones constitute what is known as the mineral or inorganic part of the soil. The vegetable matter constitutes the organic part. In agricultural soils the mineral or inorganic part is greatly predominant. The organic part makes up a very small proportion of the total weight of the soil. The inorganic part is the original part. The vegetable constituent has come from the partial decay of plants that have grown and died on and in the soil.

The inorganic constituents, and therefore the bulk of all soils, are derived from the breaking up or disintegration of rocks. The character of the soil depends greatly, therefore, on the kind of rock or rocks from which it has been derived. This is true not only from the point of view of physical character of the soil but also from the point of view of the plant food that it contains. The food used by plants in their growth is derived partly from the air and partly from the soil. Of the part taken from the soil the organic constituent supplies one part and the inorganic or mineral constituent supplies the rest.

The plant however cannot use the food until it becomes soluble in the water that is in the soil. Through the disintegration or decomposition of the rocks into soil the mineral elements of plant food are made soluble, not readily in pure water but in the soil water which carries in it certain acids derived from the air and from decaying vegetable matter.

The minerals do not all dissolve at once, however. They dissolve only from the surface of the soil grains or particles, since the water can only get at their surfaces.

The greater the surface area exposed to the soil water, the more solution will be effected, providing other conditions are favorable. It is well known that there is a larger surface exposed in a given weight of very fine particles than in the same weight of coarse particles. The finer the soil particles, other things being equal, the more concentrated is the soil solution. There is a limit to the advantage gained by this however. That is reached when the particles become so small that the open spaces between the grains are not large enough to allow the water to circulate through the soil with sufficient freedom. The air also cannot get into such a soil to do its part in making the plant food soluble.

The rock material, after being changed from rock into soil, does not always retain the position it occupied as rock. It may have been carried away by various natural transporting agents, to a greater or less distance, and dropped in another place.

Soils that have been carried away from their place of origin are called *transported soils*. They may be of local derivation, like the alluvium of small creeks, or of far off derivation like the alluvium of large rivers or the soils of glacial or wind deposits. The alluvium of small streams is usually of simple composition, partaking only of the nature of the rocks of a small region which are apt to consist of a smaller number of distinct kinds of rocks than occur in a larger region. The alluvium of large rivers and the soils of glacial regions may be of very complex origin as well as composition.

Soils that retain the same location that they had as rock are called *Residuary soils* or *Sedentary soils*. They have a very close relation to the rock on which they lie though they may not be derived wholly from it or from a rock similar in character. In many cases the soil layer in any square foot of residuary soil may be what has been left from the wasting away of rock layers many times thicker than the soil layer. A few feet of soil may be what is left of many hundreds of feet of rock. In such cases several different kinds of rock may have been wasted away and the soil may have constituents derived from each. Nevertheless residuary soils are as a rule less complex in origin and composition, physically and chemically, than transported soils.

The soils of the Ozark region, with the exception of the alluvium of the creek and river valleys and a belt of varying width along its northern border, are residuary. The valley alluvial belts are usually narrow and from the point of view of area they are not of great importance. In point of production, however, not only per acre but

total, they are very important. The rivers, with the exception of the Osage and White rivers, rise within the Ozark region so that their alluvium is of local derivation.

The belt of transported soil along the northern border of the region is probably the southward thinning edge of the glacial clay and silt layer which covers the uplands of northern Missouri like a blanket.

Soil Classification.

The terms in use by farmers such as clay, loam, sand, sandy loam, etc., are sufficient as far as they go but the soil to which these terms are applied vary widely in different localities. As used by farmers, these terms are not the result of accurate comparative study on a broad basis. They cannot be expected to be applied with any great degree of accuracy to soils in widely separated localities. Until wide areas of soil had been accurately studied by scientific methods no comparative and comprehensive knowledge of the soil existed, and under such conditions classification is impossible.

Various criteria have been used as bases for soil classification, such as the origin of the soil, the kind of rock from which it was derived, the crop to which it seemed best adapted and the natural growth found on the soil originally, such as the kind of trees or grass.

Each of these recognized one or in some cases more than one of the easily noticed differences in soils. The ideal classification would be one that would take into consideration as many as possible of the many different conditions affecting a soil, or characteristics possessed by it.

In order to describe soils intelligently and to deal with those from a large area of country where there are wide variations in soil character it is necessary to establish some facts or characteristics around which similar, though not identical, soils may be grouped. This grouping and such sub-grouping of the soils as may be effected on the basis of other characters of more restricted, though considerable, range constitutes soil classification. The characteristics around which they are grouped are recognized as the basis of classification. They (primary bases) must be common to a great number of soils.

Until within the last few years there has been in America no well defined and universally recognized basis of soil classification. Soils had not been studied in a systematic way. No great store of facts concerning them gathered from widely separated areas had been accumulated. The data were not at hand on which to build a soil classifica-

tion. Before classification of any considerable number of things, facts or phenomena, is possible a rather intimate knowledge of such objects, facts or phenomena must have been accumulated.

The only system of classification used at the present time to any important extent in the United States is the one that has been developed by the Bureau of Soils of the United States Department of Agriculture. The primary basis of subdivision is Physiography—a combination, in a broad sense, of geology and topography. The bases for further sub-classification are in categoric order, Geological formation (kind of rock) from which the soil is derived, general size of the soil particles and finally the texture and color of the soil. Other factors enter as modifying factors and are recognized in the grouping, but the factors named are the principal ones.

CLASSIFICATION OF OZARK SOILS.

General Grouping.

The Ozark region in Missouri is a unit geologically differing in all respects from the country surrounding it except a portion of northern Arkansas. Its soils are all residuary except the narrow belts of alluvium along the creeks. It forms therefore a distinct group of soils, related, it is true, to soils in other parts of the country but not to those of the immediately surrounding country. The region differs also from the surrounding country in topography. It is therefore a physiographic unit. On the basis of its rocks and its topography its soils constitute a single soil group.

The rocks of the region as a whole are limestones.

Similar, or even identical soils, may be found in other states or in other areas in Missouri but these areas, except small portions of adjoining states, are cut off from the Ozark region by intervening territory with entirely different rocks, different character of surface and different soils. Although the Ozark rocks are chiefly limestones, the region, as stated above, is not entirely made up of such rocks. The limestones are not everywhere of the same character. The character of the country also is different in different parts of the region so that there are abundant reasons for dividing up the soils of the region into sub-groups.

On the basis of the character of the country, its rock beds and its soil the region is easily subdivided into three sub-regions:

(1) The Ozark Border.
(2) The Ozark Plateau.
(3) The Ozark Center.

The Ozark Border.

The Ozark border is lower than the rest of the region as a whole. It is made up of a greater number of different kinds of rocks than the rest of the region and these rocks as a whole are less flinty than those of the rest of the Ozark region. As a whole the Ozark border is not so rough a region as the other areas. Every one of these characteristics is of profound influence in determining the character of the soil and especially its availability for agricultural purposes.

The Ozark Plateau.

The Ozark plateau differs from the Ozark border in having an entirely different group of rocks underlying it. Its rocks are more uniform in character, however, than are those found in the Ozark border belt. Were it not, therefore, for the different kinds of surface produced by the work of the rivers draining the region its soils would be rather uniform. The roughness or smoothness, and to a certain extent, the height of the different parts of this region determine the character of its various soils. This region comprises the area drained by the Gasconade river and its tributaries, the greater part of the Missouri area of the White river drainage basin, and a portion of the area drained by the Osage river.

The Ozark Center.

The Ozark center differs from either of the other two regions in the character of the rocks underlying its different parts and in its roughness. Its rocks differ widely from each other but the most of its area is underlain by very flinty rock. Its soil, therefore, is full of stones. It has two small areas, however, in which the amount of stone in the soil is very small. Taken as a whole, however, the Ozark center is a region of very stony soils, the Ozark plateau of moderately stony soils, and the Ozark border of slightly stony soils, though one of its areas has a considerable quantity of stone. The distribution of each of these areas is shown on the map accompanying this report.

Each of these areas is further subdivided into smaller groups of soils, according to characteristics having smaller areal distribution than the broad ones just described. The characteristic most abundantly used in the subdivision of the areas described above is that of character of individual rock series or layers. Some of the beds are sandstones, which decompose into a sandy soil. Some are limestone beds, free of flint, while others have a great deal. Some beds are nearly pure limestones, others have a great deal of clay. Another characteristic used is that of character of topographic detail. Very badly cut up regions are differentiated from smoother regions even though the soils

of the two areas are derived from identically the same rock. They do not have the same productive capacity, agriculturally, and should not be grouped together.

The Ozark region as a whole, following the nomenclature suggested by the U. S. Bureau of Soils, is called a soil Province. This is subdivided into three sub-provinces: the Ozark Border, the Ozark Plateau and the Ozark Center.

Each of these is further subdivided into soil series or groups as shown on the soil map accompanying this report. Beyond this the differentiation is not carried on the map though the various kinds of soils in each series, or as many of them as are known, are described under the series in this report.

In the following pages the main soil groups are first described, followed by a description of the more important soils, so far as known at the present time, occurring in each group.

OZARK BORDER SOILS.

The Springfield Soils.

Distribution.

The main area of the Springfield soils lies in the southwestern part of the state including the greater part of the area covered by Greene, Lawrence, Jasper, Newton, McDonald, Barry, Stone, Taney, Christian, Webster, Dade, Polk and Cedar counties.

The belt of rock from which the soil was derived continues on around the Ozark region as may be seen by consulting any good geological map of the state. Between the northern part of Dade county and the northern part of Benton where the belt becomes buried by other formations, it is narrow. It appears again north of the Missouri river and extends eastward as a continuous belt to St. Charles county but it is not a factor of any importance in soil formation on account of the narrowness of the belt, and its covering of clay from another source. It forms a narrow belt from the Missouri river southward through St. Louis, Jefferson and Ste. Genevieve counties. This part of it, except a small part of the St. Louis county portion, lies close to either the Missouri, the Meramec or the Mississippi river. It is rather deeply dissected, therefore, and has very little tillable land in it. In St. Louis county it is extensively covered with glacial materials so that the soil covering is not typical residuary soil.

Along the southern and southeastern parts of the Ozark region the rocks that form the Springfield soils lie far south of the state line in Arkansas.

Southwestern Missouri is typically therefore the region of Springfield soils.

Topography.

The topography of the main part of the area in southwestern Missouri is that of a plateau sloping gently to the northwest.

It is highest therefore along its eastern, southeastern and southern boundaries. It is considerably higher along the boundary than the adjacent country, to the east and southeast. Its slope to the northwest is gradual, however, while that to the southeast is steep. Small streams which, tributary to White river, drain its steep eastward slope have cut deep narrow valleys back into it for a few miles. The eastern boundary of the plateau has been made ragged by the ravines which have been cut back into it by the southeasternly flowing streams. For several miles back from its edge it is best described as a thoroughly cut up or hilly country. It consists of deep, narrow hollows and narrow, branching, stony, wooded ridges. Except where James river and its tributaries have cut a deep gash back into it, the width of this ragged border varies from five to ten miles.

Beyond the heads of these steep hollows the country becomes an even plain. This would be its character over the whole of the rest of its area were it not for the fact that this part also has creeks and rivers draining it and these have cut valleys into its surface. They are not so deep, however as those that drain its southeastern edge. Each of the rivers flowing across it, such as Spring and Pomme de-Terre rivers have made belts of hilly country along which they flow, but the hills are not so high, the valleys are not so deep and the slopes are not so steep as those along its southeastern border.

The eastern edge of the Springfield plateau, running northward from Marshfield stands slightly above the country east of it but not so high above it as the southeastern edge stands above its adjacent country. There is no river east of it as large as White river which lies southeast of it so that the ravines which drain it do not cut it up so completely as the southeastern border is cut up.

North of Cedar county the belt becomes narrow and its elevation less. It is not so high above the sea level and does not stand noticeably above the county lying east of it. Sac river has cut into it in Cedar, Dade and St. Clair counties and the Osage flows along it for some distance in St. Clair and Benton. They and their tributaries have cut the country up thoroughly but not deeply, so that a large part of the hilly land, along Sac river especially, is capable of cultivation.

The Osage belt is a little rougher because the dissection is somewhat deeper. This hilly region, along both the Sac and the Osage is nearer like the hill land within the Springfield plateau than that along its southeastern border.

In Cooper, Pettis and Saline counties the belt widens again. Its topography in Saline and Cooper is hilly, in Pettis smooth. Cooper and Saline, however, are not even so hilly as Cedar and much less so than the eastern rim of the plateau in Webster, Christian and Douglas counties.

The smoothest land within this belt and the largest area of smooth land lies in the great southwestern expansion of the belt in southwestern Missouri. There is no other area of smooth land of equal size on this formation in the world.

The Rocks.

The Springfield soil area is underlaid by the Mississippian series of geological formations. These consist of the following rocks, beginning with the highest:

1. Chester Limestone.
2. St. Louis Limestone.
3. Keokuk Limestone.
4. Warsaw Limestone.
5. Burlington Limestone.
6. Chouteau Limestone.
7. Hannibal Shale.
8. Louisiana Limestone.

It will be noticed that all these rocks are limestone with one exception, the Hannibal shale. The area, however, is not evenly divided up among these several formations. The Chester formation barely occurs in the state so that for all practical purposes it may be left out of consideration. The same is true of the Warsaw limestone.

The St. Louis limestone has a very limited distribution in the state and still less in the Ozark region. The Keokuk limestone occurs only at two places in the Ozark region and in each of these its area is extremely small. The Hannibal shale barely occurs in the Ozark region and the Louisiana limestone does not have a typical occurrence south of the Missouri river. The Hannibal shale is the soil maker within the Ozark region only in narrow belts in Cedar, Dade, Webster and Wright counties. Practically all the residuary soils of the whole area, therefore, have been derived from the Burlington limestone, the others occurring only in small areas or in narrow belts. The Chouteau limestone has a wide occurrence in the Ozark border region but it is of practically no importance as a soil maker on account of its

occurrence in narrow bands and its close association with the Burlington. The Springfield soils, therefore, are chiefly Burlington limestone soils. They are not all typical, however. It is only when they occur in broad areas that they occur unmodified. Where the area is narrow the soil is modified more or less by the next higher formation. This is the coal measure sandstone or sandstone and shale. Even in the large area of these soils occurring in the southwestern part of the state the true residuary Burlington limestone soils are covered on many of the high flat ridges and the prairies by soils derived from shaly and sandy rocks that originally overlay the whole region. These ridges are narrow, however, and the prairies small, so that the great body is typical.

Northward from this large area the character of the soil changes, but only in proportion to the amount of foreign material that is incorporated in it from other rocks. The Burlington limestone itself is very constant in character around the whole Ozark border. It is gray, rather coarsely crystalline, usually very highly fossiliferous and contains a large percentage of flint in nodules and bands. This latter varies somewhat in amount but it is so nearly universal in its occurrence in this limestone that it may be considered so. The soils are all more or less stony therefore, the flint of the rock remaining in the soil as stones instead of decomposing or disintegrating into soil. Unlike limestone soils in many regions, however, the soil layer, or rather the layer of decomposed material overlying the solid ledge rock, is thick. The ledge rock is rarely exposed except on steep slopes, the only exceptions being those localities where the soil is practically free from flint stones. Even in these places the limestone is rarely seen on smooth fields.

The Soils in General.

These soils are all silts of varying colors, running from black, through various shades of reds and yellow to white or gray. The proportions of clay and sand never or very rarely run very high in any of these soils. They are, therefore, usually mellow, or are easily made so with fair treatment. They are well drained, also, and are moderately early and warm. These characteristics are due in part to the greater or less abundance of stone or gravel in the soil. It is almost universal in its occurrence and in some of the types it is very abundant.

The subsoils are universally reddish in color. The intensity of the color varies somewhat but is everywhere greater than that of the soil. Like the soils they contain a considerable proportion of silt, very little sand, but also a considerably higher percentage of clay than the soils. The average percentage of clay in the soil runs from 10 to 20 and that of the subsoil is a little higher as a rule but rarely running above 20.

Like the soil, the subsoil has a varying proportion of stones and gravel intimately mixed with the other constituents. Where the soil is extremely stony the subsoil is slightly less stony. Where the soil has very few stones the subsoil usually has a higher proportion. The stone content in the subsoil is more constant over the region as a whole than in the soil.

The natural growth on each kind of soil will be described under each separately.

The Soil Types.

In this general report which is chiefly a reconnoisance report it is thought unwise to undertake to give exact locality names to all the types of soil, and in the cases where names have been given to them such names must be regarded as merely tentative. If in the further prosecution of the work the results of the detailed study of the areas warrant the retention of the names used in this report, they will be retained, otherwise not. The subdivision into types in this report is made partly on the basis of the physical and chemical analysis, partly on the timber growth, partly on the presence or absence of considerable quantities of loose stones in the soil, on the geological formations, on the topography, the color and the performance of the soil under cultivation.

The Stony Black Oak Silt Loam.

This is the extreme variety of the stony soils of the series. The stones, always chert, range from 25 to 90 per cent of the total mass of soil. The finer part of the soil is a silt of essentially the same physical conformation as that of most of the other types of the series. There are two phases of this soil recognized by the farmers of the region. The "white flint" soil is made up of 40 to 90 per cent of small fragments of white apparently perfectly fresh chert or flint usually from 2 cu. in. in size downward. The fragments are always angular.

The "red flint" soil is made up of 20 to 80 per cent of soft, porous rough, reddish fragments of chert, of larger average size than those of the "white flint" phase but usually not more than 6 to 8 inches in diameter with an average size somewhat less than that. The fragments are roundish due to weathering. They are never rounded as a result of having been rolled. The proportion of stones to fine part in the soil in this phase is smaller than in the other phase. The less stony parts of each phase are sometimes cultivated. The "red flint" land is considered the best. It is more fertile, lasts longer, and stands drought better.

The origin of the two phases is partly topographic and partly due to the original character of the rock from which the soils were derived. The "white flint" soil occurs on most of the southwardly facing slopes, especially if they be steep, while the "red flint" occurs on the north slopes. On these the evaporation is less and the rocks are more moist, oxidation and decomposition are more active. The cherts or flints as well as the limestone are more thoroughly decomposed. On the southwardly facing slopes moisture is soon evaporated and decomposition is retarded. On the other hand changes of temperature are more rapid, so the flint, being compact, is broken up into small pieces by the rapid warming and cooling. In such cases the differences are undoubtedly due to topographic position. Often the same narrow ridge will have one phase of soil on the south slope and another on the north.

In other cases these different phases occur in positions where the differences cannot be ascribed to the slope or exposure to the sun, but are probably due to the nature of the flint that was in the limestone before it was converted into soil.

The subsoil is a reddish, stony, silty clay essentially alike in both phases. The timber growth on this type of soil is chiefly black oak. On the northwardly facing slopes and in deep narrow hollows where evaporation is slight and the soil is usually more moist than elsewhere, red oak and white oak are most common. On the very stony ridges black oak is the most common tree. Scattered post oak and black jack trees occur also. On the southward slopes the trees are all scrubby as a rule with post oak and black jack rather common. There is no undergrowth and at the present time not much grass. Until the timber grew up dense enough to shade the ground there was a thick dense growth of the native blue stem grass. It has been smothered out by the shade and at the present time its place is taken by a thick growth of annuals and perennials, many of them being native legumes.

In portions of southern Stone and Taney counties the short leaf yellow pine has occupied much of the southward slopes and many of the dry stony ridge tops.

This soil is found in the hilly belts of the areas of the Springfield soils. These belts, as stated above, are the southern, southeastern and eastern border belt and a belt along each side of all the larger creeks and rivers within the area. Not all of the areas of these hill belts, however, are included in this type. Most of the other types of the series occur in small areas here also, but this is the dominant type. It is impossible to outline these areas on a small map. A map on a scale of at least one inch to the mile will be required and their location can only be determined by detailed work.

The width of the border belt will average fifteen miles along the southeastern part of the area and about five miles along the rest of the boundary. Along the streams the width will vary from one to five miles.

A small proportion of this soil is in cultivation. No exact statistics are at hand but it is estimated at not more than ten per cent. In the rougher parts of the border belt there are areas of several hundred square miles where not more than two or three per cent is in cultivation.

The physical analysis of the fine part of this soil is about as follows:

SOIL.

Clay	12 to 14%
Silt	60 to 65%
Sand	15 to 20%

SUBSOIL.

Clay	13 to 15%
Silt	60 to 68%
Sand	12 to 18%

No chemical analysis of a sample of the extreme phase of this type has been made because of the difficulty of collecting the samples. The sampling augur will not penetrate it on account of the great abundance of stones. Some analyses of stony phases of other types of the same series, derived from the same rocks and occurring in much the same condition as these show a low percentage of humus, nitrogen and phosphoric acid a moderately good percentage of lime and a high percentage of potash.

The proportion of humus is low both because of the open porous and dry nature of the soil which favors the rapid burning out of the humus by weathering and because of the autumn fires which have spread over these hills from time immemorial. Before the timber grew dense enough to smother out the grass with shade the autumn fires burned the dead grass. Since that time they have burned the leaves. No vegetable matter has been allowed to accumulate on the land. There is no layer of mold that is gradually changing to humus, nor has there ever been.

It is not easy to supply rapidly the humus under cultivation on account of the difficulty of plowing effectively among the stones. It is rather difficult, on that account, to get vegetable matter thoroughly mixed with the soil.

This soil is not adapted to the growth of the general farm crops on account of the difficulty of cultivating it and its low fertility. Its less stony phases, however, are well adapted to the growth of clover and other legumes. These plants "catch" readily and do not die from drought badly nor are they subject to freezing out. The land is so rough however, that a hay crop cannot be harvested easily. Clover fields can be utilized for pasture, however, with excellent results. White clover grows well and spreads rapidly especially during wet years. It is rather easily affected by drought.

Bluegrass and the other sod grasses do not grow well partly on account of the lack of humus and nitrogen in the soil. There are indications, derived from observation on this soil that the growing and pasturing of clover for a few years will enable blue grass to take hold. The great abundance of clay and silt in the fine part of the soil ought to make it an ideal soil for grasses of all kinds. The poor growth of grass cannot be due to the coarseness of the soil but is more probably due to the low percentage of humus. This can be supplied by proper handling.

The bunch grasses, especially orchard grass, grow quite well on this soil. They grow much better, however, after some humus has been supplied.

A great deal has been said about the fruit industry on this soil. There is no doubt that fruit trees will grow on it and will produce good fruit but it will never be possible to devote all or even a large proportion of these lands to the growth of fruit. The fruit crop is uncertain in that region on account of winter freezing and late spring frosts. It is extremely unsafe to depend on fruit growing alone as an industry. As a branch of general farming it can be made to pay.

The existing area of fruit culture can and will be extended in this soil but a point will soon be reached where the utilization of the best of it for pasture and the poorest for the growth of timber will be found more profitable than fruit growing.

The salvation of the area lies in a combination of fruit culture and grazing with the growth of legumes as important pasture plants. A farm on land of this soil alone, could not be a very profitable one. When it is owned in considerable bodies, however, and once set in clover and other grasses it can be used to great advantage as pasture land on farms which include some areas of the other soil types of the region, especially the bottom land soils on which hay and grain can be grown for feeding. Such pasture lands are cheap, fencing materials are cheap and when once set in grass and clover they will support almost as much stock per acre as much higher priced land in other parts of the state.

Handled in this way, the less stony phases of this soil can be made profitable. A rotation in which a large reliance is placed upon legume crops and in which grain crops are not grown too frequently is to be strongly recommended for this class of soils. For the more stony portions the most profitable crop that can be grown on them is timber. It is not a soil for the small forty-acre farmer except in the immediate neighborhood of the towns or a railway station where the growing of small fruits can be engaged in with a moderate degree of profit.

Whether this soil will grow alfalfa or not is a question that has never been settled. It is quite probable that alfalfa could not be started on it without heavy fertilization but where properly prepared there is no sufficient reason yet shown why it should not grow, at least on the less stony places. The roots could penetrate to great depth and the clayey nature of the subsoil would hold water through prolonged drought. There is no real hardpan under this soil.

The Black Oak Gravelly Loam.

The finer parts of this soil do not differ essentially from that of the preceding type. They are both derived from exactly the same kind of rock and through the action of the same processes. They are both residuary upland soils. They differ in their topographic location, their proportion of stone and the ease of cultivation. The Black Oak Gravelly Loam varies in color from place to place from gray to yellow, brown and red. A greater proportion of the area of this soil has a reddish color than that of the preceding.

The proportion of stone, above a cubic inch in size, is considerably less than in the preceding type, rarely running higher than 15 to 20%. It is not so high as to make it unprofitable to haul the stones off the land. This is often done and the land made much more easily tilled. The amount of stony material less than one cubic inch in size varies from five to 40 per cent, running higher and lower only in rare cases. The proportion of stony material is about the same in the soil and subsoil.

The fine material of the soil consists of about 60% of silt, 10 to 15% of clay, and about 10% of sand, though in places the proximity to localities where the overlying sandstones of the coal measures occur modifies the amount of sand in the soil layer considerably. It does not affect the subsoil, however, to a great extent. The percentages of clay, silt, and sand in the latter are about 25 to 30, 45 to 60 and 5 to 15 respectively.

The timber growth on this type of soil is Black Oak and Red Oak to the practical exclusion of every other variety of tree growth

except occasional White Oaks which occur on the northwardly facing slopes. Like the timber everywhere on all the soil types of the Ozark region, that on this type has grown up since the occupation of the region by white man and the stopping of the prairie fires. Before that time there was a growth, often very dense, of hazel and sumac brush. Just as such land is now described as "Black Oak land," a large part of it was formerly known as "hazel and sumac" land. At the present time occasional sugar maple trees and a few shrubs or small trees are usually found on the northwardly facing slopes.

There is no large area made up wholly of soils of this type. In general, the areas are small and more or less isolated. They occur chiefly in the hill belt of the Springfield series area, that is, in the southern and southeastern border belts and in the river and creek hill belts of the interior. They are closely associated therefore with the stony Black Oak soils. They occur, however, in the smoother parts of these hilly areas higher up the streams than the latter soils and on the gentler slopes. They do not occur, as a rule, on the flat topped ridges however narrow they may be. They are hilly or rolling land soils. They are derived from massive nearly pure limestone beds which carry a small amount of flint. In decomposing or disintegrating into soil, therefore, there is not a large amount of flint to be left in the soil. The same beds of limestone underlie much of the area of the more flinty type but only on steep slopes where the flint from higher beds which carry a much greater proportion of flint, has drifted down over the whole slope and made it all stony. The gravelly soils occur on the more gentle slopes on which the creep or drift from above is not sufficient to affect the amount of flint in the soil.

It is impossible at present to give the details of distribution of the soils of this type. To do that will require accurate detailed mapping.

A much larger area of this soil is in cultivation than that of the preceding type. It occurs more often on northwardly facing slopes and is better adapted to cultivation for that reason alone than the southwardly facing slopes. It is regarded as a strong soil in comparison with the other upland soils of the region though the physical and chemical composition of its fine material is practically identical with that of the preceding type. This latter, however, although a strong soil, is not cultivated to any extent on account of its content of stone. What was said concerning the crops that may be grown on the stony black oak soil applies here also. For the first few years after clearing it will produce fairly good crops of corn and wheat but on account of the small amount of humus in the soil to begin

with this kind of cropping soon reaches the lower limit of profitable production. The small amount of humus is soon burned out and the nitrogen used up. Its store of mineral fertility, however, has not been seriously reduced by these few years of cropping and the soil being naturally a legume bearing soil, the growth of a few crops of clover or cowpeas, especially if one or two crops are turned under, brings it back to better condition than it had to begin with. This kind of farming, however, cannot be kept up indefinitely, for by it no mineral matter is given to the soil and considerable is being taken away in the crops of grain and clover. The soil as stated above is low in phosphoric acid and the time will come relatively soon when it will be necessary to add phosphoric acid to the soil.

Like the stony type of soil it is better adapted to grazing than to grain or hay raising on account of the unevenness of the land and on account of the stone in the soil. The physical condition of this soil, where it is treated with any sort of intelligent regard for the maintenance of its fertility is almost ideal. The fine material is almost wholly silt and clay but it contains so considerable an amount of gravel of all sizes that it is kept in a mellow condition. In cases where the land has been cultivated in corn for several years in succession and the humus all burned out it is inclined to bake when dry. When it reaches this condition it will, if abandoned or allowed to lie fallow for a few years, become covered with a dense growth of young sassafras brush.

Although both these soils occur in the hilly area of the Springfield soils yet they do not wash badly as a rule. The only reason for this is the presence of the stone and gravel in the soil. These enable the soil to absorb the larger part of the rainfall rather than to cause it to flow off on the surface. The stones act as obstructions to the flowing water also and hinder washing in that way. It is only where the amount of stone and gravel is very small that there is much loss of soil from washing. The streams of the region are clear excepting for a very short time during freshets. When ditches are started in the fields they are easily stopped by being filled with stones.

The Black-Jack Gravelly Loam.

This is a gray, brownish yellow to yellowish silt with a varying proportion of stone and gravel. The soil at the surface is usually gray but changes to a yellow or yellowish red color in a few inches, becoming continually a more decided red downward. The gray part of the soil rarely extends to greater depth than ten inches, and is usually less. The subsoil is some shade of red or yellowish red, being more often reddish than yellowish though not usually so deep

a shade of red as the subsoil of the two Black Oak types already described.

The proportion of stone varies greatly, more than in either of the Black Oak types. In places the stone constitutes from 50 to 60 per cent of the total soil material and as a rule occurs in large angular masses as well as small fragments or gravel. In fact some of the most hopelessly stony areas of the whole Springfield series region belong to this type. The flint masses are large, sometimes more than a cubic foot in content, white, angular and undecomposed. The other extreme is that in which the soil is practically free from stone of any kind larger than a cubic inch or two in size. Rarely is this soil free from the latter and it usually occurs in quantities amounting to more than 10% of the bulk of the soil. Where the large stone is absent the small stones or gravel do not make cultivation especially difficult.

A physical analysis of a sample of the fine material of this soil from McDonald county showed 23% sand, 64% of silt and 11%clay, while the subsoil from the same locality showed 21% sand, 49% silt and 24% clay. This is probably not far from an average composition of this soil. The percentage of sand in this sample is probably a little higher than the average in this soil.

This soil type includes the area in which the principal tree growth is the Black-Jack Oak or Jack Oak or Black-Jack and also the gravelly parts of the small gray soil prairies of the southwestern part of the state within the Springfield soil area. The Black Jack brush has encroached rapidly on these prairies since prairie fires were stopped by man except where the land has been placed under cultivation. Black Jack is almost the only tree that grows on this soil. An occasional Post Oak and an occasional hickory may be met with.

This is one of the two main types of soil in the Springfield area that occur in the smoother parts of the region. It occurs on the broad gravelly prairie areas, on the somewhat rougher land on the boundaries between the prairies and the hill belts and on narrow, gravelly ridges.

This soil occupies, therefore, with the one next to be described, the central part of the Springfield area. It is confined almost wholly to the western side of the Ozark region and is found chiefly in the southwestern counties. It does not occur in its typical form on the eastern or northern side of the Ozark area.

A large part of the area of this soil is now in cultivation. When the uplands began to attract the attention of farmers this soil was the first to be put under the plow. This is due not to its greater fertility than that of the types described above but because of the smoothness

of the country and the lack of a heavy growth of timber to be cleared off. It is in fact universally regarded as poorer land than that of the preceding types but is much easier put into cultivation and easier to cultivate when once broken out. Its growth of timber was never dense. It is much more so now, where not cleared and in cultivation, than ever before. Probably about 70% of this area is now under fence and most of what is cleared and broken out is under the plow.

The physical analysis shows that this soil is adapted to general farming. Its chemical analysis shows, like all the other soils of the Ozark region, a low percentage of nitrogen (.118%), phosphoric acid (.055%), and of lime (.137%), and a high percentage of potash (—), and of magnesia (.171%).

It is devoted to the growth of wheat and corn chiefly—in fact almost exclusively—with an occasional crop of oats or clover.

On account of the smoothness of the land farm machinery can be run over it and its yield of wheat is fair so that it is devoted to the growth of that cereal more than to any other. The next most important crop is corn. It yields under favorable conditions of season and tillage and while the humus content is still fairly good, about 35 bushels of corn and 10 to 15 bushels of wheat. Of late years farmers have been using considerable bone meal with wheat, increasing the yield up to 20 bushels in good years.

It is not regarded as a good clover soil. It does not catch so well as on the Black Oak types and does not grow so rank. Not nearly so much attention is paid to growing it as on the latter types. The soil is, however, fully as much in need of it as any of the other types and sooner or later it will have to be done or else the growth of other legumes will have to be taken up. Phosphoric acid will also have to be added in time unless more attention is paid to live stock husbandry and all manure carefully saved and put on the land.

Grass is not grown to any extent on this soil. It is rather too dry, loose and open to be especially adapted to such a crop. The main thing, however, that makes the growth of grass unprofitable seems to be the lack of humus in the soil. In a few localities where this has been supplied, blue grass gradually takes possession and forms a good sod but does not grow so rank as it grows on the clay lands of the northern part of the state, except where an abundant humus supply has been derived from clover.

Orchard grass and the other bunch grasses do quite well. The southern grasses such as Bermuda have not been tried on this soil. There is very little doubt that the growth of a few crops of clover or cow peas, turned under, will supply the necessary constituents for the successful growth of Blue grass. When this is done the continuous

cropping of grain crops can be stopped and the land still handled profitably.

A larger proportion of this soil is devoted to the growth of fruit than that of either of the other types described. This not due to its greater adaptability to the growth of fruit trees or plants but rather to the fact that it is an upland soil and a larger proportion of it lies adjacent to the railways. The fruit growing localities are determined largely by the location of transportation lines. It is generally agreed that fruit trees do not grow so well on the upland prairie and gravelly Black-Jack soils as on the Black Oak gravelly soil.

The danger from late spring frosts is not so great on the upland as in the valleys. The fruits grown on this type of soil are apples, peaches and strawberries. A crop of the latter is a little more certain than of the former and they usually find a good market. The industry is large enough to enable the product to be shipped in carload lots. The chief losses have resulted from heavy rains at the time of harvesting. Other small fruits do well but no effort has been made to grow them for the market except locally.

Of the two tree fruits mainly grown in the region, apples are more extensively grown and are more profitable. The peach crop is made very insecure on account of spring frosts. Apples are often injured also though a total failure is rare, so also is a full crop. The latter probably once in six to eight years, the former once in ten.

The area devoted to fruit or that is likely to be devoted to fruit in the future is small proportionally. The bulk of the area, therefore, will be devoted to general farm crops and to live stock husbandry. To make this permanently successful it is absolutely necessary to get the soil in the condition to grow grass. This can be done by putting humus and nitrogen into the soil and keeping it there. The easiest way and the cheapest way to do this is by the growing and plowing under of clover or cowpeas—not by the harvesting of a crop of hay and turning under the stubble but by turning under the whole crop. For land that is to be put to grass one or two crops turned under will be sufficient if the grass be pastured. When the land is to be devoted to grain or hay growing this will have to be done, in the case of grain growing, every three or four years, or with hay every six or eight years. Where grain crops are grown continuously even with clover in the rotation, it will be necessary before long to apply phosphorus in the form of some mineral fertilizer as well as return all manure to the land. Lime is another thing that will benefit this soil in places but it must not be thought of as a fertilizer nor as a material that can take the place of the clover and phosphorus fertilizers. All three of these things are or will soon be a necessary con-

dition for the growth of profitable grain crops on this soil. No one of them can supply the requirements. The lime can be obtained easily and cheaply in the vicinity, the clover can be grown. The only thing that will cost more than labor and seed will be the phosphorus.

The Post Oak Silt Loam.

This is a gray bluish or yellowish stony to stone free soil with a bluish to yellowish or grayish stony to stone free subsoil. It is largely a silt, the fine material in the soil giving a percentage of 13 for clay, 69 for silt and 15 for sand while the subsoil gives the percentages of 31, 53 and 14 for clay silt and sand respectively.

The stone constituent of this soil is chiefly "chunk" rock, consisting of stones varying in size from 5 to 10 inches in diameter with a very small percentage of gravel. In many cases the gravel constituent is absent leaving a stony to stone free silt.

The subsoil is, as stated above, bluish to yellowish or reddish yellow or mottled though rarely as red as the subsoils of the Black Jack type. Its stone constituent is somewhat greater than that of the soil though not so great as that of the other types. The proportion of gravel is about the same as that of the soil down to a depth of from 24 to 30 inches, below which it usually increases. Where the soil is stone free the subsoil, at least down to about 24 inches is apt to be free also and of a rather tough blue clay.

The timber growth on this soil is almost exclusively post oak. It graduates into the gravelly Black Jack land on the edges, the latter tree appearing in small proportion at first and gradually increasing.

Before the occupation of the country by white man the area of this soil type consisted of oak openings, or open grass covered areas with few trees of large size, exclusively of post oak. The ground was full of roots, however, which sprouted up every spring and were regularly killed down every fall by fires. When white man stopped the fires these sprouts grew rapidly, except where the ground was cultivated, and have produced a very dense growth of tall rather smooth saplings almost exclusively of post oak. Many of the old trees still stand and rise above the tops of these young oaks. The annuals growing on this land originally consisted chiefly of grasses. Legumes were not entirely absent but they were much less abundant than on the gravelly types.

Since the growth of young trees became sufficient to shade the ground the grasses have been killed out so that now the ground is bare or supports only a few weeds. The leaves, however, are burned every autumn so that the store of humus is not being increased.

This is an upland soil. It occurs on the flatter areas of the country, on the flat topped ridges, the flat, poorly drained areas or "flatwoods" of the native nomenclature, and in the flat sag-like valleys on the uplands—usually around the heads of prairie sloughs. The total area of this type of soil is smaller than that of any of the types already described. There are very few large bodies made up exclusively or chiefly of it. Its occurrence is usually in small patches in sags and on flat ridges where the drainage is poor. Like the Black Jack soil area it occurs almost exclusively in southwestern Missouri, and is more abundant in Webster, Greene, Lawrence and Barry counties than elsewhere. North of Dade county it is hardly known and along the northern and eastern sides of the Ozark region the Springfield belt is narrow, near the Mississippi river and too well dissected for the occurrence of any significant areas of this soil.

A rather smaller proportion of the area of this soil is under cultivation than of the preceding type. It has the advantage of being free of gravel and occasionally free of stone but the greater disadvantage of being cold and poorly drained. It is considered the poorest of the tillable upland soils of the region. It is rather hard to work and requires a favorable adjustment of many factors to produce good crops. At the present time it is farmed just like the other upland soils of the region. It is devoted to the general farm crops, which in this region consist almost exclusively of corn and wheat. In some cases these post oak areas are converted into permanent timothy meadows, but little attempt has been made to improve the land by manure drainage or other means except an occasional application of commercial fertilizer. It produces fairly good crops of timothy and red top hay but poor crops of corn. The dryer portions, the stony portions with yellowish or mottled subsoil will produce fair crops of wheat but the stone free phase with the blue clay subsoil produces very poor crops of wheat except in rare cases when the seasons are dry.

Clover does not grow well on a large part of this soil. It will produce fair crops in favorable seasons on the better drained stony areas but on the blue clay subsoil areas it will not grow profitably under existing conditions.

The dryer areas will produce good crops of cowpeas and they will grow in the other parts so that there is no reason even with these soils for buying commercial nitrogen nor for leaving the soil forever barren of humus.

This type of soil has not been studied very much but the indications are that it is badly in need of nitrogen, humus and lime. These can all be supplied cheaply by the farmer himself. One sample from this type has been analyzed chemically and the result showed a low

percentage (.179%) of nitrogen, a low percentage of phosphoric acid (.04%), a low percentage of lime (.149%) and a high percentage of potash (.27%).

These results do not differ greatly from those of the preceding type though the percentage of phosphoric acid is somewhat lower. The defect seems to lie in the physical character, in the poor drainage, the dense nature of the subsoil, and the low percentage of sesquioxides of iron present. It must be borne in mind, however, that these figures are for a single sample only and no broad generalizations can be based on them.

The farmer of this soil as well as some of those on the Black Jack soil report the occurrence of a hardpan from one to three feet below the surface. No systematic study of these occurrences has been made but in the few cases studied nothing but a stiff or tough clay layer was found except that in some of the Black Jack areas the stone, a few inches below the surface, became for a foot or so more abundant and more closely compacted but no place has yet been found where such stony layer or clay layer was cemented into a definite impervious hardpan layer.

The flat areas of the Post Oak belts with the blue clay subsoil will be improved with drainage. Whether this will have to be done by open ditches or by under drainage cannot be stated here. An application of lime (600 to 1000 pounds per acre) and the growth of a few crops of cowpeas would bring this soil into much better condition. Fruit trees seem to do about as well on this soil as on the preceding type. Not a great deal of it however, is devoted to growing fruit. Strawberries are not grown on it to any extent, the dryer gravelly Black Jack soils being much better adapted to them.

The Bottom Land Loam.

This is a gray to black loam or silt loam, rarely passing into a sandy loam, with or without gravel. It is everywhere of an open, friable texture having sufficient clay and silt to enable it to hold moisture but not enough to make it difficult to cultivate. It is free of stone of large size, larger than an inch or two in diameter except where a ravine or hollow from the hills opens out into an area of level bottom. In such cases, the wet weather streams have washed stones from the hills and spread them out in cone fashion around the mouth of the hollow. The gravel in the loam is always more or less rounded and oxidized to a reddish color.

The subsoil is either a reddish clay or gravelly clay of that color. The gravel is usually in layers and lenses alternating with clay, and rarely or never cemented into an impervious layer. There are on

most of the larger streams two or more benches or terraces, usually two well defined ones. In such cases the upper bench has a clay subsoil with a small amount of gravel down to three or four feet while the lower bench, the modern alluvium, usually has a gravel or gravelly clay subsoil.

The timber growth on this soil consists of white, red, burr and pin oak, sycamore, walnut, elm (two species), hackberry, wild cherry, butternut, white and black hickory, mulberry, sassafras, persimmon, pawpaw, and a rather long list of shrubs and vines, all of which grow luxuriantly. The more gravelly parts of the bottom lands were devoid of large trees and grown to sumac and hazel brush until the occupation of the region by white man.

These soils are confined to the creek and river bottoms. They lie, therefore, in long narrow strips. They are rarely more than half a mile wide and from that down. The average width of the alluvial strips is about three-eighths of a mile for the region as a whole. The narrow bottoms of the small hollows in the hills where there is no stream, except during heavy or protracted rains, are not included here, since the bottoms of such valleys are mere long narrow strips of soil that is but a little more than a bed of loose stones.

Practically the whole of the area of these soils is in cultivation and has been so for many years. The first farms of the region were made on them. The lands where they occur have always been the highest priced and most profitable lands in the Ozark region, and are especially well adapted to general farming. They produce good crops of corn, wheat and clover. Oats is grown to some extent, but the yield is not enough to make it a paying crop as a rule, the reason probably being climatic. The yield of corn, when a corn-wheat-clover rotation is run, and the soil handled carefully, will average about forty bushels per acre, running in favorable years to sixty or more, while it rarely drops below thirty. The yield of wheat under the same conditions will average twenty bushels except where it is cut down by rust or climatic influences.

Clover yields one and a half tons of hay and from one to four bushels of seed per acre. Blue grass does not grow luxuriantly, partly because no attempt has been made to set it and none is likely to be made. The land is too valuable for growing grain. The gravelly silt soil is rather loose, also, for the sod making grasses. Orchard grass where it has been tried has done well. These bottom lands will probably never be converted into permanent pasture. This will be located on the adjacent hill land. The profitable farm in this region, therefore, will include at least a small area of bottom land for grain growing and a larger area of upland for pasture and clover hay.

The water supply in these valleys is abundant and of good quality.

With a rotation of corn, wheat, clover, the turning under, rather than the burning, of the waste and the return of the manure made from the feeding of the corn and clover on the place, back to the land these soils will produce grain crops indefinitely with the addition of mineral fertilizers occasionally.

The Bolivar Soils.

The Rocks.

The soils included under this name are derived from rocks of the lower carboniferous age lying just beneath the limestones which form the soils of the Springfield series. They are the Hannibal shale and sandstone. They occur as clays, clay shale and fine-grained sandstone of a prevailing yellow to greenish yellow color. Since the shale is much more abundant than the sandstone, the soils are more often clays than sands. The sandstones are very fine-grained and earthy.

The average thickness of these rocks is only 30 to 50 feet. The width of the belt of country in which they constitute the surface rock is narrow, often not more than a mile, though occasionally amounting to twice or three times that width. From the areal point of view, therefore, they are not very important rocks. They usually outcrop on slopes which are capped by the limestones which form the Springfield soils. The soils overlying them, therefore, are rarely derived wholly from them. Soil from the limestones has usually drifted down over them so that the surface soil is often considerably modified and only the subsoil is typical Bolivar soil material. On the other hand, the clays from these rocks sometimes extend out over flat areas as a thin layer of soil with a subsoil made from underlying rocks of a totally different character. These two main modifications of these soils occur on the outer and inner borders, respectively, of the belt.

The Soils in General.

These soils are prevailingly of a somewhat cold clayey nature, and where they occur over an area of considerable width the country is usually flat. This emphasizes their tendency to wetness. Except where stones have drifted down over them from near-by areas of Springfield soils they are wholly free from loose flint stones. Where the sandstone is well developed, small boulders of soft earthy, yellowish, perforated sandstone may occur. Where the subsoil is derived from the next underlying formation on the inner border of the belt it is stony. The timber growth on this soil is, on the more clayey

portions, chiefly laurel oak and post oak. The post oak grows on the flat areas and the laurel oak on the gentler slopes and in the small valleys. On the sandier parts black oak and red oak are the important trees, though black jack is not uncommon. On the bottom lands laurel oak with the common bottom land trees such as elm, walnut, cherry, etc., are found.

These soils do not form a continuous ring around the Ozark region. Like the Springfield soils they are southwestern Missouri soils and occur chiefly in Webster and Polk counties. A narrow belt extends into Hickory county as well as into Cedar, but they disappear before reaching the Osage river. They do not reappear again in the whole circumference of the Ozark region.

They are practically unknown south of the Springfield-Memphis line of the Frisco railway. The rocks producing them gradually thin out southward and, although they extend south of the railway, they are so thin that they do not influence the soil. They begin as a narrow belt near Cedar Gap and extend northward in a rather narrow belt immediately east of the Springfield soils through the country in which Marshfield, Fairgrove, Pleasant Hope, Tremont, Bolivar, Polk and Elkton are situated. Beyond this they rarely occur, but they are found in narrow belts along Sac river and its larger tributaries in Cedar and Dade counties. The belt is not continuous, unbroken and of even width along the course described. It is cut by streams as well as by eastward projections of the Springfield series and is broken by outlying islands of the latter. It is broader, but more broken up, in Polk county than anywhere else.

Timber Growth.

The timber growth consists of mixed oaks, post oak on the flat areas, red and black oak on the better drained areas and laurel or shingle oak in the wettish upland sags.

The Soil Types.

Only two general types of soil are known to belong to this group. *The Polk silt loam* is the upland soil of the group. It is gray to yellowish in color, free from loose stones and on account of the general smoothness of the topography in which it occurs is nearly all in cultivation. It is rather heavy and intractable, but under favorable conditions will produce fair to good crops of wheat and corn to which it is largely devoted. The wheat stubble fields in the autumn are usually covered with a growth of *Spanish Needle*. It is in need of drainage on the flatter areas and in the upland laurel oak sags which are rather abundant.

The Polk Loam.

This is the bottom land soil of the area, but very little of it occurs. The streams practically all cut through the bed of shale and into the underlying cherty limestone. The alluvial soils partake therefore of this latter rock to a considerable extent. The Polk loam occurs unmodified only in very narrow belts along the small streams. It is dark to black in color, rather sticky, with a silty to fine sandy subsoil.

There are doubtless small areas of fine sandy soil derived from the fine sand beds of the shale, but such areas were not seen.

The Perryville Soils.

Distribution.

The Perryville soil belt or ring is, like the two just described, only a partial one, not extending entirely around the whole Ozark region. It lies, however, on the eastern side of the Ozark region rather than on the western.

The Rocks.

It is underlaid by limestones belonging to a wide range of geological ages, from the lower part of the Ordovician to the Devonian, all alike, however, in being rather pure, chert-free limestones. The soils are therefore chert-free silts and clays, either red, gray or some shade of yellow or brown depending upon the formation from which they have been derived and the amount of leaching to which they have been subjected. The formations, beginning with the lowest, is a gray subcrystalline limestone of Lower Silurian age which weathers to a rather yellowish soil. It is about 100 feet thick and of essentially uniform character from top to bottom.

The next formation is the Trenton limestone, which has two divisions, a bluish fine grained crystalline lower half and a coarser crystalline gray upper half. Both weather to reddish soils. The next, which is a group of several beds belonging to the Upper Silurian and Devonian ages, consists of beds of limestones of varying character, all of them chert free, however. There are also a thin bed or two of shale.

These formations all lie along the eastern part of the Ozark region extending from the Missouri river in the western part of St. Louis county southward to the lowlands of Cape Girardeau county. They dip eastward beneath the rocks making up the Springfield soils, such of them as occur along the eastern side of the Ozark region. This belt of rocks leaves the Missouri river in the western part of St. Louis county. Through St. Louis and Jefferson counties the belt of their outcrop is very narrow and the soil overlying it has been modified to

such an extent by the adjacent Springfield soils that it does not differ essentially from them and has been included in that group. The typical Perryville soils do not appear north of Riverside, where the Mississippi river turns to a southeastward course. From this point southward the belt widens very slowly continuing as a narrow band entirely across Ste. Genevieve county. At the south line of the county it widens rapidly and occupies a broad belt across the eastern part of Perry and the central part of Cape Girardeau counties. In Ste. Genevieve and Jefferson counties, the rocks forming the Springfield soils lie between the Perryville belt and the Mississippi river. In the southern part of Perry and all of Cape Girardeau county the belt is cut off from the Mississippi by the intervening belt of Wittenberg soils.

Topography.

The topography of that part of the belt of country underlaid by this soil which lies north of the latitude of Ste. Genevieve is rough. The belt is narrow and lies close to the Mississippi river. It is rather high also. This has resulted in its complete dissection. The soil is everywhere badly eroded and in most places the top soil is gone leaving the subsoil only. In fact, in places the rock is entirely bare.

South of the latitude of Ste. Genevieve, as the belt widens it becomes smoother. Over its whole area in Perry county, except a belt along the river a few miles in width, it is a rolling plain, becoming somewhat hilly along the creeks. The creek hills are rounded, rock beds being rarely exposed and the uplands have many gentle undulations due to sinks in the underlying limestone. The chief factor controlling the value of this soil for agricultural production is that of topography. Where the land is relatively smooth the soil is well adapted to general agriculture. It differs in this respect from the Springfield soils where a factor of considerable importance is the quantity of loose stones in it which determines its agricultural value more often than any other factor.

This whole region, uplands and valleys, was covered with forest when white man first saw it. The luxuriance of the forest growth was one factor in attracting settlement. It was one of the first upland areas of the Ozark region that attracted settlement and the upland farms on it are among the oldest upland farms of the state.

In geological formation, topography, physical constitution, color, origin and fertility, the soils of the greater part of this area are practically identical with the soils of the limestone belt of the great Appalachian valley in Pennsylvania, Maryland, Virginia, Tennessee and Alabama. The Bureau of Soils of the U. S. Department of Agriculture has named these soils the Hagerstown Soils.

The Soil Types.

There are, so far as our studies up to the present time have enabled us to classify the soils of this belt, two types of soil in it. These are the Perryville silt loam and the Perryville clay loam. As the region is studied further other types will probably be found. Our classification into two types only, is an extremely broad, simple one that is evident to every casual observer and is based on a very hurried study. This belt has received less study than any other belt of its size in the Ozark region.

The Perryville Silt Loam.

This is a reddish brownish or gray silt loam, having about 8 to 15 per cent of clay, 65 per cent of silt and 10 to 20 per cent of sand. It is practically free from loose stone, such as do occur being fragments of limestone as a rule. Fragments of chert or flint are rare. The surface drainage seems to be sufficient except on small areas where former sink holes have been filled up. It is mellow, easily cultivated and under proper treatment, produces good crops.

The subsoil is a reddish silt differing from the soil chiefly in its deeper red color and a somewhat higher percentage of clay. There is no sharp boundary between soil and subsoil. The soil section gradually changes from the paler color of the soil to the deeper color of the subsoil accompanied by a gradual increase in the percentage of clay. Analyses of the subsoil show a percentage of clay varying from 10 to 20, of silt varying from 55 to 70 and of sand varying from 18 to 22, depending upon the depth. The clay increases and the other constituents decrease in depth.

The subsoil rests directly on the bed rock and usually at a depth less than 30 feet. The limestone, being nearly pure carbonate, is decomposed only by solution, so that its surface always presents the appearance of fresh rock. Except where the occasional shaly beds underlie the soil there is no gradation from one to the other, though the lower layers of the subsoil contain many detached masses of limestone.

The Perryville silt loam, being free from gravel, stones, and coarse sand is a cooler soil than those of the Springfield series. Its humus burns out more slowly under the same treatment, yet on account of the cropping system of practically every farmer on it, its supply of humus is low at present. This type of soil is farmed almost exclusively by Germans and has been farmed by them for a great many years. The few exceptions to this rule do not affect the cropping system because the system of the majority determines it. The Germans in Missouri are grain farmers. The live-stock farmer among them is extremely rare. They have practically taken possession of the lands on the eastern and northern borders of the Ozark region. This is a region

of stone-free silt and clay soils, and a rolling hilly topography. Their system of exclusive grain farming has reduced the humus content of these Ozark border soils to a very low per cent and has also caused the soils to wash badly. The two redeeming features of their methods of farming are their careful use of the little barn yard manure that they get and their rotation of clover with the grain. This, however, is not sufficient to supply the necessary humus, nor is it conserving the supply of mineral plant food, especially phosphorus.

The forest trees growing on this soil are laurel, red, pin and white oaks, hickory, walnut, cherry, post oaks, hackberry, elm, maple.

There is relatively little timber still standing that is of much value. In the more rolling parts there is still some good white oak timber and everywhere there is enough red, pin and post oak to supply local demand for fuel, posts and the rougher building material.

The exact distribution cannot be given. It can only be stated that this soil occupies the smoother parts of the belt as described above. In Ste. Genevieve county it begins two or three miles north of Zell church, is only about a mile in width and runs thence south to the Saline creek breaks. After an interruption of a few miles along the hill belt of the creek, it appears again south of the creek and soon spreads out so as to include the whole east central belt of Perry county and the central belt of Cape Girardeau county. In these latter counties it is interrupted only along the creeks. It is the soil of the rolling uplands. Probably ninety to ninety-five per cent of this soil is in cultivation and has been in cultivation for nearly a quarter of a century—some of it much longer than that. An uncleared area on the rolling upland is a rare occurrence.

Along the slopes, in the ravines and hollows, there are still plenty of trees, but on the smoother lands they have long since been cut off.

The fact that this soil has been selected to so great an extent by a race of grain farmers is of itself an indication of its adaptability to these crops. This is not the only factor or possibly not the chief one that caused the settlement of the Germans on this land, yet it is certainly one of considerable importance.

The main crop is wheat. The exact proportion of the area in wheat to that of the total area of plowed land cannot be stated but it is approximately 40 per cent. Corn comes next with probably 25 per cent, and the other crops follow, clover being the most important.

Fertilizers are not used to any significant extent. The yield of wheat will average 12 bushels and of corn about 30, though in favorable years it will run five or ten bushels higher.

This is one of the best soils of the Ozark region. With proper handling its productive capacity can be easily maintained for an indefinite period. It is probably low in its phosphorous content, but with

a proper system of farming that supply will suffice for almost an indefinite period. It may be increased, however, by the addition of commercial phosphates which on this soil, under intelligent direction may be done profitably.

Its physical character is excellent and its location good. The system of farming now adopted is not calculated to maintain its fertility. It is absolutely essential that more humus be added, that the nitrogen supply be maintained or increased and that the exhaustion of the mineral fertilizers by continuous wheat crops which are sold off the land be stopped. In other words, a system of live-stock farming must be adopted, the grain grown on the land must be fed back on it and a rotation with more grass in it must be established.

During the last few years some of the farmers have begun the growing of cowpeas because of the increasing difficulty of growing clover. They are cut off for hay, however, rather than turned under and do not supply enough organic matter to the soil. The growth of clover is becoming more and more difficult throughout the whole Ozark Border German belt, due to the exhaustion of the humus and possibly the phosphorus and lime of the soil by continuous grain cropping.

Whether this soil needs lime or not is not known. That is a subject, however, worth investigation.

The Perryville Clay Loam.

This is the surface soil made from the subsoil of the silt loam where the latter has been eroded away. It is the hill land soil of the region, therefore. It is of a reddish color except where its exposure has been long enough to weather it to a gray by leaching out the iron oxide. It is sticky, tough, rather difficult to work, gray yellowish or red in color and usually shallow. There is very little change in character, down to a depth of three feet. The subsoil is a little deeper red in color and has a slightly higher per cent of clay.

Ledge rock is often exposed, sometimes in the fields, while in many cases the fields occupy the narrow ridge tops, extending down the slopes on each side to where they become so steep that both soil and subsoil have disappeared and the bare rock is exposed. Fragments of limestone are not uncommon, though they are too scattering to be of any value in preventing the washing of the soil. They are usually larger than the average size of flint fragments found in Ozark soil.

The natural growth on this soil is red, black, post and white oak, with a varied assortment of shrubs and brush. Post oak is the most abundant tree with red and black following and white oak last. The flatter and more eroded places as well as the more thoroughly leached places support post oak. It never grows on the red colored soil, if the

color is a decided one. Chinquapin oak is often found where the soil is shallow and the bed rock frequently exposed.

This is the hill land soil. It occupies the tops of narrow ridges and the slopes of the badly dissected part of the belt. It occurs in irregular belts along the creeks and a rather large area lies along the heads and near the heads of the short streams flowing into the river. It does not extend entirely up to the river, being separated from it by a belt of brown loam soil whose origin is not yet certainly determined, though it is probably a river or glacial deposit. It lies, however, between this and the valley lands of the silt loam area.

A much smaller proportion of this soil is under cultivation than of the silt loam. The percentage will not run higher than 40.

It does not produce heavy crops of anything. The same methods of farming are carried on as on the silt loam. It is devoted almost exclusively to grain growing with a little higher percentage given over to the tame grasses, usually timothy. Wheat is the chief crop and corn the next. The yield of wheat per acre is not more than 10 bushels, while that of corn, except where the land is manured heavily, is not more than 25. It is better adapted to wheat than corn. Cowpeas grow moderately well but are not grown to any important extent.

The two things that this soil needs above all others is vegetable matter and nitrogen. Its supply of mineral fertilizers is not less than that of the silt loam. The vegetable matter will lighten the soil, and make its water holding capacity greater as well as remedy its extremes of wet and dry conditions which are now a serious drawback. The nitrogen will supply the plant food that is now deficient.

Both these can be supplied cheaply and effectively by the plowing under of cowpeas or clover. The growth of these crops and their harvesting as hay will not affect the result because no more humus nor nitrogen is added than is taken away in the crop.

The next most effective way is the addition of barnyard manure in large quantities, but this is impossible for the whole of these soils simply because it cannot be obtained.

The next best method is the plowing under of all sorts of, and every crop of, weeds and the addition of commercial nitrates, which will probably be unprofitable to the man who undertakes it.

A slower way is to convert all this land into pasture.

The Hillsboro Soils.

Distribution.

The next ring of rock and soil coming inward toward the center of the Ozark region is also an open ring. It also lies along the eastern and northern part of the Ozark region and does not

appear on its western or southern side. Along the northern part of the region, also, it lies north of the Missouri river, so that for our present purposes that part of it need not be considered. It runs from the Missouri river in the extreme western part of St. Louis county southward through St. Louis, Franklin, Jefferson, Ste. Genevieve, Perry and Cape Girardeau counties. It barely touches the northeastern corner of Bollinger county. It is bounded on the east by the Perryville group belt and on the west by the belt next to be described.

The Rocks.

It is underlain by a sandstone which retains its characteristics rather well along its whole course. The bed is rather thin, never exceeding 150 feet, dips eastward and outcrops usually in a rather steep slope that faces westward. The actual width of outcrops of the rock is often less than a quarter mile and rarely more that half a mile. The sand, however, which determines the character of the soil occurs in a belt much wider than the width of the rock belt. The sandy soil belt has its eastern boundary on the eastern boundary of the rock belt, but its western boundary is further west. The rock originally extended further west and in being worn back to its present position it left considerable sand in the soil. Sand also has been washed from the stone and spread out over the smoother land immediately west of it. The amount of sand in this belt varies considerably becoming less and less westward. The subsoil in going westward across the belt departs more and more from the subsoil of the typical sandy soil and partakes more and more of the nature of the next belt of soil to the west.

The width of the belt of sandy soil, where it leaves the Missouri river is about five miles. In the vicinity of Hillsboro it is about ten miles. Through the northern part of Ste. Genevieve county it is rarely more than two or three miles and in Perry it is not prominent on account of the thorough dissection of the belt. In the northern and central parts of Cape Girardeau county it is about five miles in width.

It continues southward and ends against the northern side of the Southeast Missouri Lowlands.

Topography.

Only the northern and southern ends of this belt are utilized to any extent for agricultural purposes. From the Missouri river southward to the northern part of Ste. Genevieve county a considerable portion, probably about 40 per cent, is in cultivation. It is a rather hilly region but the valleys are not so deep and so abundant as to leave no land smooth enough for cultivation. Through the greater part of Ste.

Genevieve and Perry counties, on the other hand, the country is so badly cut up with narrow valleys and ravines that it is practically useless for anything but timber growing and for pasture. The bed of sandstone also seems to be rather thin along this part of its belt so that it is not a prominent factor in soil formation. The ravines are cut deep into the rock beneath the sandstone leaving nothing but sharp-topped ridges to be occupied by the sandy soil. This washes easily so that in most places it soon disappears. South of Apple Creek, however, the country is considerably smoother, and the belt of Hillsboro soil, although quite narrow, is occupied to a considerable extent with farms. The largest area of this soil that is cultivated lies in Jefferson county. It extends northward into the eastern part of Franklin, also. In Ste. Genevieve and Perry counties it is mostly hilly and uncultivated while in Cape Girardeau it is again cultivated.

Timber Growth.

On account of the fact that the sandstone bed whose distintegration has produced this soil outcrops in a narrow belt barely more than a mile in width with a steep westward slope, the greater part of this soil belt lies west of the outcrop of its parent rock. The soil lies therefore on a rock of a different kind. This affects, more or less, the nature of the subsoil. This is true particularly of the western and northern parts of the belt. It is less true for the eastern and southern parts. In the western part of the belt, therefore, the surface soil is sandy, while the subsoil has a higher percentage of clay and is often stony. The roots of trees reach downward through this thin sandy soil and into the stony clay subsoil. On account of this the timber growth is essentially the same as that on the soil next to be described. It consists of black, red, white, and post oaks, with scattering hickory on the upland.

On the eastern side of the belt where both the soil and subsoil are derived from the parent sandstone the soil is dryer and the timber growth consists chiefly of scrub oak.

The Soil Types.

There are two main types of soil in this area, an upland type and an alluvial type. The latter is of rare occurrence. It never occurs unmixed with material from other soil and rock belts because of the elevation at which the country lies with respect to the level of the valley bottoms and the narrowness of the belt.

The Hillsboro Loam.

The soil varies from a loam through sandly loam to an almost pure sand. The distribution of these phases of the soil depends on the dis-

tance from the outcrop of the sandstone and the local topography. The loam lies along the western side of the belt and on slopes where the sand has become mixed with some of the clay from the underlving rocks. The sandy loam occupies the middle part of the belt and the sand occurs in patches chiefly in the eastern part of the belt. The loam usually has a rather clayey, sometimes stony subsoil, the other two phases have more sandy subsoils.

A sample of this soil collected in the northern part of Ste. Genevieve county showed 26, 60 and 11 per cent of sand silt and clay, respectively, in the soil and 28, 45 and 26 per cent in the subsoil. A chemical analysis of a sample from Jefferson county contained a low percentage (0.073 per cent) of nitrogen, a low percentage of phosphoric acid (0.952 per cent), a good percentage (276 per cent) of potash and a low percentage (0.312 per cent) of lime.

One of the most noticeable features of the country in the Hillsboro belt of soils is the somewhat ragged appearance of the fields due to gullying. The topography is rolling to hilly. The soil is very friable. It washes into gullies easily. Where not carefully handled the fields are pretty badly washed by the time the stumps are out. It is especially liable to receive poor treatment. It is not naturally a very fertile soil. It does not occur in large bodies of smooth country where it can be cultivated easily. It does not respond with a bountiful yield and great profit to thoughtless, careless treatment. Furthermore the larger area of it lies in Jefferson county, where it is too far from St. Louis to be of great value as a truck soil and not far enough to overcome, with its rather moderate promises of reward, the stronger attraction of the city. The young men leave the farms to the old people, or to renters. It is not a soil that can stand the average renter very long.

It is not a hopeless soil, however, by any means. It is warm, porous, easily, though not cheaply cultivated, has no hard pan, has sufficient clay in its subsoil to hold a good store of moisture, does not leach excessively, is no poorer in the elements of fertility than many other more highly cultivated soils and grows clover and other legumes luxuriantly. A soil with these characteristics is not hopeless. It can easily, with intelligent cultivation, be made the home of a great many prosperous farmers.

The crops now grown on it are corn, wheat and clover. These are the crops to which it is best adapted and it will grow them with profit providing it is not allowed to wash badly and its supply of humus is kept up by plowing under a crop of clover occasionally. Not more than one crop of corn should be grown in a rotation period of about four or five years.

The Union Soils.

Distribution.

The Union belt of soils lies next to the Hillsboro belt on the west and runs parallel with it. Like the latter, the Union soil belt extends around only the eastern and northeastern part of the Ozark region. It begins in Bollinger county on the northern boundary of the southeast Missouri lowlands. Its boundaries are not sharp lines, there being a gradual change eastward into the Hillsboro soil and westward into the Reynolds belt. The latter, however, is sharper than the former. The line is very crooked, however, being driven eastward by east-west hollows and westward by similarly trending ridges. In general its western boundary runs northward a few miles west of Zalma and continues thence about due north to the southwestern corner of Ste. Genevieve county. It runs thence northwestward by Ulam, Weingarten and the northwestern corner of the county. Thence it passes by Vineland, Frumet, Lone Dell to Moselle. It then turns southwestward and follows approximately the line of the St. Louis and San Francisco railway to the vicinity of Rolla, where it turns north, then northeastward, and finally, after much turning, reaches the Missouri river a few miles west of Washington in Franklin county. Throughout Bollinger and Perry counties it is about ten miles wide. In Ste. Genevieve it is narrower, becoming very narrow in the southwestern part of Jefferson county. After turning westward its width is considerably greater though very irregular.

The Rocks.

The rocks from which this soil is derived, consist of magnesian limestones with a rather small amount of flint. The layers are usually rather thin, and there are occasional dark to greenish shale layers. As a rule the rocks are fine grained and are rather impure. The impurity is clay. This gives the rocks, with their fine-grained character, a rather dull earthy appearance and a rather smoothish fracture. Granular crystalline beds occur interbedded with the others, but they constitute a considerably smaller proportion of the rocks than the other. When these rocks disintegrate into soil, the lime is dissolved out and carried off in solution in the streams, and the clay is left behind. There being a rather small proportion of flint, there is not much of that material left as stone in the soil.

The Soil.

The soil and subsoil consist, therefore, of nearly stone-free to moderately stony limestone silt and clay with a gray to yellowish color, passing downward into a yellowish to pale reddish clay subsoil. The

subsoil is rarely deep red. Where the land is level the soil may have a very dark or nearly black color.

Topography.

The whole of this belt of country is a rolling to hilly region. The greater part of it lies along watersheds, or is crossed by small streams only. Castor river runs within it for a few miles only; Whitewater and Crooked Creek dissect it to some extent in Bollinger and Madison counties, but neither cut deep enough to render any considerable part of the county unfit for agricultural purposes as a whole. A considerable portion, about 30 per cent, is made too rough to cultivate but these areas grow timber or grass. In Ste. Genevieve county it is badly cut up and a considerable portion rendered unfit for agriculture. A belt across it on either side of the Meramec also is rather rough, but only moderately so, so that a considerable portion of it is in cultivation. Elsewhere it is gently to strongly rolling or moderately hilly.

Timber.

The whole of this area is timber land except where cleared and in cultivation. The principal trees are white, post, red, laurel and black oaks on the uplands and the usual Ozarkian bottom land timber in the valleys. White oak and post oak, the latter predominating, make up the larger part of the timber. White oak is abundant on the northward facing slopes and on the yellowish clay hills. Post oak is the dominant tree on the more level-topped ridges and is mixed with the white oak on the narrower ones. Accompanying the white oak on the northwardly facing slopes are red oaks while black oaks usually accompany the post oaks on the flatter ridges, especially where rather well drained. They occur with the white oaks also, especially on the southerly slopes. Laurel oak occurs only in the northern part of the region and in moist, gently sloping valleys and sags.

The Soils in General.

The soils of this region are stone-free to moderately stony silt to clay soils, either gray or yellowish in color. The proportion of stone in them is least in the southern part of the belt and greatest in the northwestern part. The small amount of stones, the fine grain of the soil and the rolling character of the ground are all favorable to soil washing. With the exception of a narrow belt lying along the St. Louis and San Francisco railway it is practically all subject to erosion. This keeps the top soil pretty well washed off, and does not permit the accumulation of a layer of humus-rich soil on the surface, when treated

in the ordinary way. The rather fine grained soil does not permit as rapid burning out of the humus as is the case with the more stony Ozark soils but it is rather easily washed off. Under careless management it does not accumulate. In this respect this belt does not differ much from the other Ozark soils. It is not a region, however, of old, worn out, gullied and abandoned fields. The land that has been cleared is all cultivated with more or less care. One reason for this lies in the fact that it has been almost entirely occupied by German farmers. While they are not very successful in increasing or even maintaining the humus supply of the soil they do not allow it to wash into gullies. There is a great deal of loss of soil due to washing but gullies are not allowed to deepen indefinitely.

Probably not more than 40 per cent of the total area of this belt is in cultivation. A considerable part of it can never be cultivated on account of its steepness and the shallowness of the soil. Probably about 60 to 70 per cent of the area can be made to produce either grain or grass. The rest will grow timber more profitably than anything else.

The upland soils of the whole area do not differ widely from each other. The most striking difference is in the proportion of stone. There seems to be no persistent regularity in its distribution so that no more can be said about it than has been said above. The soil of the western part of the southern area and of the southern part of the western area of the belt are apparently poorer than the eastern and northern parts respectively. They are the parts also most nearly free from loose stones. There are two possible reasons for this. The former soil lies only on the tops of high ridges while the lower slopes belong to the next belt of soil to the west. It has occupied this position a long time and has been badly leached. A large part of its mineral fertility, and especially its lime, has been leached out of it. On the other hand the soil along the eastern and northern parts of the respective areas of the belt are continually being freshened by the erosion away of the leached soil and the exposure of a more recently formed lower layer. The second possible reason for this difference of soil lies in the possibility that the better soils lie adjacent to the Hillsboro belt and may be lightened up somewhat by a small amount of sand. This, however, is a rather doubtful possibility.

The Crops.

The crops that are grown on this soil are the usual grain and hay crops. The acreage of wheat and corn on the upland is apparently about equal. The yield of wheat is 8 to 20 bushels, the latter only after clover or with bone meal, and of corn on the uplands about 30 bushels. Clover can be grown with reasonable success on all this

belt except the most thoroughly leached lands. On these cowpeas grow well.

This soil is not naturally so fertile as the Perryville soil and occupies a more broken country, has a larger percentage of stones and is paler in color except locally where crystalline limestone layers occur. It has an even greater deficiency of humus, phosphorus and lime and is more subject to erosion. It is naturally stronger however than the Hillsboro soil and has been more considerately treated. Its greatest need is humus. The next is nitrogen and the next phosphorus. As stated many times already it is necessary to purchase only one of these, the phosphorus. The rest can be grown.

The Owensville Soils.

Distribution.

There are two general areas in which this soil occurs in bodies of considerable size. The easterly one occupies the highest part of the Ozark border plateau lying east of the Gasconade-Osage hill belt. It lies in Gasconade, Franklin, Maries and Phelps counties, chiefly in the former. The westerly area lies in a smilar topographic position on the west side of the Gasconade-Osage hill belt. It lies in Morgan, Northern Miller, Moniteau, Cooper and Benton counties.

The Soils in General.

This is a series of loam soils white, gray or black in color with a clay subsoil. The subsoil is reddish to brownish at top changing downward to bluish and at 24 to 30 inches to a yellowish mottled color. The thickness of the soil layer down to the reddish subsoil runs from 6 to 16 inches where best developed. It is underlaid by a sandstone in many places yet it is rather low in sand and what sand it has is fine sand. The sandstone bed underlying it is not continuous, but its lack of continuity is due to erosion so that if the soil were wholly residuary it would be sandy, Along the breaks where the typical area of this soil grades off into the wholly residuary soil there is a considerable percentage of sand and in some places a very sandy soil. This fact as well as its occurrence indicates that it is an outlying area at the southern edge of the Kansas glacial soil much like that of northeastern Missouri though no granite or crystalline material has been found in it. In many places it is underlaid by a bed of well-worn chert pebbles though this layer seems to be very patchy. In other places it is underlaid with a layer of very fine clay, some sand and a great many small polished though not well rounded chert fragments. The same material is found in small patches in several other places on the northern bor-

der of the Ozark region and is known to extend southward as far as Cuba and possibly to St. James. The Owensville region, however, is the only one where it occurs over a large unbroken area of any considerable size.

Another universal characteristic of this soil is the occurrence in it of a great many small round black iron concretions about one-tenth of an inch in diameter. The grayer the soil the more abundant are these "buckshot."

Topography.

The topography is everywhere smooth, varying from a very gently undulating to a somewhat strongly rolling or faintly dissected plain. The western area has a larger proportion of smooth land than the eastern one.

Timber.

The greater part of this area was, until the beginning of the 19th century, either prairie or very open woods. At present the central flat ridge is still prairie though brush is rapidly encroaching on all of it that is not cultivated. The fringing woods are largely post oak. In those places where the land is flat it is almost exclusively post oak. Where the drainage is better it has a sprinkling of red oak, black oak and hickory. There are three general types of this soil sufficiently distinct to be easily made out by a hurried examination.

The Owensville Silt Loam.

This is the original uneroded surface soil or at least the least eroded surface soil in the region. It occurs on the prairie at Owensville extending westward nearly to Canaan and eastward and northeastward for five miles. There are also small patches of it in the vicinity of Drake. It is a gray to black loam with about 15% of clay, 50 to 60% of silt and about 20% of sand. The clay percentage in the subsoil as a whole from the top of the reddish layer downward is 20 to 30. A chemical analysis of a sample taken a mile west of Owensville gave a fair percentage (.176%) of nitrogen, a low percentage (.057%) of phosphoric acid, a very high percentage (.449%) of potash, a low percentage (.215%) of lime and a high percentage (.688%) of magnesia. It is a good wheat and timothy soil and raises fair crops of corn. The flat areas need drainage and the heavy cropping with wheat is exhausting its supply of phosphorus. Its supply of organic matter is fair but the soil would be better if it were increased. With good treatment, a legume in the rotation and phosphorus added in bone meal or phosphate rock the soil will last indefinitely.

The Lane Silty Clay Loam.

This is apparently a phase of the Owensville soil that is a poorer soil, probably due in part to erosion and in part to original character. It is less loamy in character, the whitish layer with small polished gravel is nearer the surface and the soil is grayer in color. Its fertility is much lower, judging from the farm houses and crops as seen on a hasty trip. It is a poor wheat as well as corn soil, except where by erosion it has become mixed with the residuary soil from the underlying limestone.

It occurs in a considerable body lying north and south along the Bourbeuse-Gasconade watershed, chiefly west of the Owensville area which lies east and west along the Bourbeuse-Missouri watershed. Its extreme northward point lies only a few miles south of Hermann while a small isolated area lies at St. James on the Gasoncade-Bourbeuse watershed and apparently another at Cuba. It is probable that detailed work will disclose many isolated areas along the Frisco railway east of St. James as well as elsewhere. The typical area is on Lane's prairie in the eastern part of Maries county. In most places except on Lane's prairie it is covered with a dense growth of small post oak saplings with scattering black oak and hickory. Until the country was occupied by white man the whole area was either prairie or else was occupied only by scattering post oaks. These still exist in many places making a marked contrast with the younger generation which covers the land with a dense thicket.

The soil contains about 12% of clay, 60% of silt and 25% of sand, based, however, on an analysis of a single sample. The subsoil has a higher percentage of clay, is rather tough and close. It does not differ essentially, so far as physical analysis indicates, from the Owensville silt loam but its growth of post oaks and its lower crop producing capacity differentiate it from the latter with sufficient clearness. It is the more leached fringe of the Owensville soil and, if it be of glacial age, most of it was deposited at a greater distance from the ice than was the Owensville silt. A chemical analysis of a sample from Belle showed a low percentage (.029%) of phosphoric acid, a medium percentage (.201%) of nitrogen, a medium to rather low percentage of potash and a fairly good percentage of lime.

The clay or silt layer carrying the smooth chert fragments is exposed in many of the roadside ditches in Lane's prairie but it is rarely seen on the Owensville (Douglass') prairie. Both this and the Owensville silt loam are entirely free from stone. Wheat is the principal crop on the Owensville soil while hay is grown on the Lane soil. A casual examination fails to show a great amount of difference between these two soils except that the latter soils do not appear loamy.

The farmers in the country say that there is considerable difference in their producing capacity.

The Owensville Stony Silt Loam.

This is merely a connecting link between the Owensville and Union soils. Running out on the long watershed ridges that radiate from these high plateau-like prairies there are long strips of a gray buckshot silty soil with more or less flint in it, underlaid by a yellowish more or less stony subsoil. The latter is undoubtedly residuary while the former seems to be a remnant of Owensville silt that has not yet been eroded off of these ridges. It extends southward as far as the St. Louis and San Francisco railway.

The Osage Soils.

Distribution.

This soil occupies a hilly region lying between the western edge of the Owensville plateau and the eastern edge of a similar plateau lying in Morgan and Miller counties. The northern side of the Osage soil belt extends to the Missouri river and the southern side lies a few miles north of the Rock Island railway.

The Rocks.

The rocks underlying it are magnesium limestones, much like those underlying the Union soil belt though they are somewhat finer grained and have a smaller proportion of flint. The soil, therefore, is almost entirely free from flint fragments. Along with the clay that has resulted from the decomposition of these limestones there is a greater or less amount of the Owensville silt and clay that originally extended over this region before it had been cut to pieces by the valleys and ravines that now traverse it. The proportion of this latter material is probably small except on the few areas of rather high flat country.

Timber.

The timber growth consists of a much larger proportion of softwood trees than any other soil area yet described except the Perryville. The most abundant trees are red oak, white oak and hickory with walnut, hackberry, elm, cherry, coffeebean, chinquapin oak, and a great variety of dogwood viburnum, thorn and other shrubs. On the dry ridges and southerly slopes the timber is sometimes scrubby.

Topography.

This is a very hilly region. It is the gateway through the Ozark border for the exit of the Osage and Gasconade rivers from the in-

terior of the Ozark region. Both these rivers have cut deep valleys and their innumerable small tributaries have thoroughly dissected the country for some distance on either side of the main stream. The area extends from the central part of Gasconade county on the east to the central part of Miller county on the west and makes a rather long northwestern projection through Cole and Moniteau counties into the extreme northeastern corner of Cooper county. It is the roughest part of the Ozark border with the exception of small areas in Jefferson and Ste. Genevieve counties and the southeastern border of the Springfield plateau.

The Soils in General.

The upland soil consists of a stone-free, grayish yellowish or brownish silt loam. A strip along the northern boundary of the area has soil that approaches the Union soils in character while the soils in a similar strip on the south grade into the Vienna and Lebanon soils. They differ from the Union soils in their paler color, more clayey and less silty-texture and in the rougher topography in which they occur. They differ from the Vienna and Lebanon soils in being much less flinty and having a more yellow color. They cover the country rather uniformly even on rather steep slopes. The rock beds are frequently exposed but not over wide areas. In addition to the silty soil underlying much of the larger areas of the country there are occasional small areas of stony clays. These are small, are not cultivated and do not need description.

The Gasconade and Osage rivers have strips of bottom land of the finest quality but they are rarely more than a quarter of a mile in width. These bottom lands are all in cultivation.

This area of country is occupied almost exclusively by German farmers. The small inland towns have a decidedly German appearance with substantial and well-preserved but plain dwellings, gravelled streets, heavy stone walls and excellent brick or stone churches.

The same crops are grown here as on the Union and Perryville soils. Clover until recently was one of the main crops but during the last five years it has become increasingly difficult to grow it. It doesn't catch well and dies out rather easily. This is probably due to the exhaustion of the organic matter and lime. Probably clover would grow if these deficiencies were supplied.

The Howell Soils.

Distribution.

The only member of the Ozark border soil belts that extends across the southern boundary of the state from Arkansas into Missouri consists of a stony red limestone silt or silty clay stretching across Ripley,

Oregon, Howell and parts of Ozark counties. The eastern end of the belt lies on the edge of the southeast Missouri lowlands. The western end lies against the rough stony gray lands of the central part of Ozark county and its northern boundary is defined by the southern edge of the rough stony land along Eleven Points and Current rivers.

Topography.

The country is rolling to hilly. In Howell and the southwestern part of Oregon counties the country is rolling. The valleys are shallow and the slopes are gentle. In the Eastern part of Oregon the belt is crossed by the Eleven Points river where it is very rough. Between the Eleven Points and Current rivers it is moderately hilly and another hilly belt lies along the latter stream. The northeastern part of Ripley and the adjacent parts of Butler and Carter counties are rather smooth.

Timber.

The whole region is covered with timber except where cleared. The timber growth is chiefly black and red oak with small amounts of white and post oak.

The Soils in General.

The upland soil has a reddish to gray color and the subsoil is deep red. The upland soil is covered with a great abundance of loose flint stones. Only very rarely is it stone free. Unlike most of the other stony soils of the Ozark region however the stone in the Howell soil lies largely on the surface. Beneath the surface there is not nearly so much of it. This is due partly to the fact that the stone constituent of all soils gradually works to the surface and also, and to a greater degree, to the fact that this stone did not come from the rock that made the greater part of the soil but from an originally higher flint layer. The flint was not so abundantly distributed through the rock but there was once a thick layer of solid flint whose position was above the existing surface, that has been broken up and the fragments left on the surface. There are still left a few high hills in the region, rising considerably above the surrounding country, that are capped by the original flint layer. The top of the hill at Sterling is one; King's Mt., east of Willow Springs, is another and the high hills in western Howell and around Spring Creek in Ozark are capped by it. Elsewhere it has been broken up by the wearing down of the country and the fragments only left on the surface.

There are four principal types of soil in this group. They are the (1) Gray Stony Loam, (2) Brown Silt Loam, (3) Gray Silt Loam, (4)Alluvium.

The Gray Stony Loam.

The stony upland soil is a grayish silt at top changing to brownish and then reddish within a few inches from the top. Like all of the other residuary soils of the Ozark region there is no definite line between the soil and subsoil. The former becomes more red in color gradually and more clayey in character downward. The soil cannot be defined as the grayish top of the whole soil layer since this is only a very few inches thick in some places and several feet thick in others depending upon the amount of leaching that has gone on.

The soil is very low in organic matter and full of stones.

The timber growth consists of red and black oak, black jack, post oak and scattering hickory and white oak. On the southward slopes it is scrubby. It is nowhere very large.

On account of the stony nature of this soil only a small part of it has been put into cultivation. Along the railway considerable areas of it have been planted to fruit trees but elsewhere a large part of it is still in timber.

The Brown Silt Loam.

Scattered over the surface in many places are small sags or basins lying from 5 to 20 feet below the surrounding rim with a stone free or nearly stone free soil. They vary in size from a few hundred square feet up to several acres. Most of them are small, too small to become important factors in the soils of the county. They are usually surrounded by very stony land lying somewhat hummocky, the stone being more abundant on the hummocks. These small details of the surface occur chiefly in the more level parts of the region. They are the results of the unequal solution of the underlying limestone. The small basins are places where the limestone has dissolved more rapidly and allowed the surface to sink below the general level. The fine parts of the soil from the surrounding higher ground have then been washed into the basins. The stones in the basin are covered by it. On the rim of the basin and the hummocks of higher ground the finer parts of the soil have been washed out and the stones are left more bare than usual. There are areas of considerable size where the surface is chiefly a succession of these features. Other areas occur, especially near the streams, where their occurrence is rare. The same soil occurs in the rather broad round bottomed shallow valleys of the smoother parts of the area. These occur in that portion of each valley lying below the head water ravines and above the point where the drainage area is large enough and the valley low enough for the formation of a perennial stream. They are usually about a quarter mile wide, occasionally twice that width. The side slopes are, as a rule,

gentle while the adjacent hills are rarely higher than 100 feet above the valley bottoms. The soil is not true alluvium but is silt and clay washed from the adjacent slopes. It is dark brown in color, is practically free from stone, is all in cultivation and is fertile. The valley floors are not level like alluvial valleys but slope gently from the bluffs to the stream channel.

The Gray Silt Loam.

Along the tops of the ridges in the areas not affected by the processes just described are often narrow strips of stone free silt to clay soil. It is gray in color and rests on a stony red clay subsoil. The change from the former to the latter is usually a sharp one. This is apparently the oldest, and therefore the most thoroughly leached soil in the region. Its character here, however, is essentially the same as it is in many other places in the Ozark region where it occupies the tops of the highest ridges. It often has a whitish, ashy appearance due to its silty character and low humus content. Its timber growth is chiefly scrubby black oak and black jack. On wettish places post oak grows while black jack grows on the dryer, better drained land. There is a tendency for the top layer of the subsoil, usually having a greater amount of chert than lower down, to become cemented into a hardpan layer. This is usually local, however, seemingly not occurring under any very large area. On account of this hardpan, the leached character of the soil and its low humus content it is not a highly productive soil. It needs humus badly. If this were supplied abundantly in the form of barnyard manure or legumes plowed under the soil would be greatly improved. It does not grow clover well. Cowpeas grow well however and can become, under proper care, the redeemer of this soil.

Alluvium.

The other soil of the region is the bottom land alluvium. This occurs along all the larger stream valleys. They are all rather narrow. The soil is brown to grayish silt and clay loam to gravelly loam.

Crops.

Owing to persistent advertisement during the eighties and early nineties a large amount of the stony uplands of this region were sold and considerable areas were cleared and planted to orchards, especially near the railway line. Hundreds of men with no experience whatever and with very little more money were induced to buy land and plant orchards. Many of them thought that all that was necessary was to plant the trees and then wait for the harvest. Such ideas were

fatal. On any soil and in the most favored of climates such ideas do not produce results in fruit growing. On the soils of this region only one result could be expected. That has been abundantly realized. Hundreds of acres of dead and dying fruit trees in brush grown, barren, so-called orchards can be seen. Fences are down and in many places the material burned by woods fires; cottages and more ambitious houses are racked, unpainted and unoccupied. There is a general absence of an air of prosperity. This is not wholly due to the soil. It is largely due to the credulity of men whose training made them wholly unfit for doing the skilled work required of the successful fruit grower. Such men had to learn that young fruit trees as well as young corn must be cared for, cultivated, pruned and defended from insect enemies. That has been learned. Henceforward orchards will be planted in this region by men with some other equipment behind them than blind enthusiasm. Large areas of this land are not adapted to fruit culture, nor to any other crop that has to be cultivated. The land is too stony. Such portions of the area as cannot be profitably set to grass may be utilized in the production of timber.

In the extreme southeastern corner of the area colored for Howell soil on the map is a small area of another soil. At the time the map was colored this area had not been studied closely enough to warrant its differentiation from the Howell Soils. It is only the northern end of an area of soil that occurs over a considerable area in the adjacent part of northeastern Arkansas. In Missouri it occurs in Ripley and Butler counties in a small area in the vicinity of and south of Pander in the former county and in a narrow strip along the extreme eastern border of the Ozark hill region in the latter county. The soil is gray to brown in color and is practically free from flint fragments. The subsoil is brown to red in color, rarely greenish or gray and is likewise practically free from stones. Like most soils derived from limestone it is shallow and on many slopes the limestone rock is exposed. Occasional areas of practically bare limestone ledges of considerable size occur. They are called cedar glades.

This is a moderately fertile soil, is easily cultivated but inclined to wash rather badly when the humus has been burned out of it.

The topography is rolling, the greater part of the area however can be utilized either as tillable land or for pastures. It seems admirably adapted to Bermuda grass.

THE OZARK PLATEAU SOILS.

Location.

The Ozark plateau as here defined occupies the western central part of the region. It occupies the greater part of the drainage basin of the Gasconade river and most of the Missouri part of the White river basin. As a whole it is a plateau with valleys. Taken as a whole its elevation is greater than that of either of the other main soil division areas. This, however, is not sufficient to be a factor of any importance whatever in the agriculture of the area. The average elevation of the uplands is about 1250 feet above sea level.

Geology.

It is underlaid chiefly by beds of limestone, the upper layers, the ones underlying the higher areas of country, having a moderately high percentage of flint. The deeper layers, those that are exposed only in the deeper valleys, have a much higher percentage of flint and weather therefore into a much more stony soil. Along part of the eastern boundary of the region there is a belt of sandstone which disintegrates into a sandy soil. It does not extend along the entire length of the belt, but occurs chiefly in Dent county.

Topography.

From the point of view of roughness of country due solely to the number and depth of valleys and ravines, this region consists of two rather different areas; a southern and a northern. The southern area is much rougher than the northern on account both of the number and of the depth of the valleys. The dividing line between the two areas is the Memphis line of the St. Louis and San Francisco Railway. The southern area is drained by White river and its tributaries, the northern one by the Gasconade and the Osage. In the southern area the stream system is a widely branching one in which the tributaries are arranged, with respect to the main trunk stream as well as to each other, like the branches of a tree are arranged with respect to the main body of the tree as well as to each other. The upland ridges between streams having such an arrangement are bound to be crooked and very irregular in width. When this is the arrangement of valleys and ravines in an area that is filled with them and one in which they are all deep, the roughness of the country is evident. The northern area on the other hand is drained, as a whole, by long streams running for a long distance parallel to each other. Their tributaries are rather short or else run more or less parallel to the main streams. The valleys also in the area, except those of the very largest streams, are not so deep as those of the southern area. Between the streams

there are long relatively broad and smooth ridges widely different from the narrow crooked ridges of the southern area. They partake of the nature of long strips of plateau. They are especially characteristic of considerable portions of Texas, Dent and Laclede counties, but occur in only slightly less perfect development in the rest of this area. Narrow belts of very rough country lie along each side of the larger streams.

At the present time the area of Ozark plateau soils is covered with timber except where cleared for cultivation. There was timber on the bottom lands when the country was first visited by white man but until within the last half century the upland was either prairie or very open woods. The timber was not dense enough to shade the ground nor to obstruct long distance views to any great extent especially in the winter time. Grass covered the ground in summer with a growth as high as the back of a horse.

The bottom land timber is essentially the same as that on the bottom lands of the Springfield soil area. The upland growth is Black, Red, Post and White Oak, Black Jack and a sprinkling of Hickory. Most of these trees have their own special habitat. They do not all occur in the same localities. The long strips and areas of high plateau constitute the typical home of the post oak and the black jack. These trees occur however in other topographic positions occasionally, but always in places where the soil has somewhat the same character as that of the plateau. The Black oaks occur on the stony ridges in the areas of rough country, the Red Oak, on the moister areas and on the slightly better soils of the hilly areas, while white oak occurs on north slopes and sparingly mixed with the other timber elsewhere but chiefly in the rougher country.

The Soils in General.

There are four general groups of soils in the plateau area of the Ozark region. Three of them are limestone soils or at least lie on limestone rock while the fourth is a sandstone soil. The three limestone soils are all more or less stony, are silt or clay soils, have a gray, brown or yellowish color with a reddish clay subsoil, are low in organic matter and low in phosphorus. The different groups are separated from each other on the basis of topography, timber growth, kind of underlying rock, color and the percentage of loose stones in the soil. The main basis for the subdivision of the area into the groups on the map is that of topography and character of underlying rock.

Each of the groups of soil shown on the map has several types or kinds of soil. The groups only are shown on the map. They are designated as the Lebanon, Vienna and Salem groups.

The Lebanon Soils.

Distribution.

This group of soils occupies the high ridges and plateaus of the area. It occurs along two main belts, one lying between the Gasconade and Osage drainage basins, the other between the Gasconade and the White river systems. Running northward from each of these belts are subordinate belts of greater or less width and length. They lie along the watersheds between the main tributaries of these streams. There are however no tongues or belts of corresponding length or width running southward from the main belts on account of the short distance to the main streams on this side. The southward flowing tributaries are in all cases short, the northward flowing tributaries are long. The northern belt is followed by the main line of the St. Louis and San Francisco railway while the other is followed by the Kansas City-Memphis line of the same railway system.

The Soils.

These soils are gray, silty, with a varying percentage of stones. They are the oldest soils of the Ozark region, have been subjected therefore to leaching and weathering for a greater length of time than any other group of soils in the plateau, have a paler color as a rule and are covered chiefly, where not cleared, with scrubby timber. The largest areas of smooth land in the plateau are in the Lebanon soil area. Its most persistent characteristics are its growth of scrub timber, its smoothness, its relatively small amount of stone and the height of the country on which it lies. The following types of soil are found in the area of this group:

Black-Jack Gravelly Silt Loam.
Post Oak Silt Loam.
Black Oak Stony Loam.
Post Oak Stony Clay Loam.

The Black-Jack Gravelly Silt Loam.

This is the most prominent type within the group and occupies the largest area of any of them. It occurs typically in Laclede county, occupying the greater part of the western half of the county. Lebanon stands in the center of this area. It extends southwestward into Webster but not in a large body. An area of it lies in southwestern Camden and northeastern Dallas and small areas exist in many other parts of the plateau region.

This type of soil occupies the slightly rolling lands of the Lebanon soil area rather than the smoothest portions. It lies within the smoother part of that region but does not occur in the very smoothest

parts of this smooth area. It is rolling enough to furnish good natural drainage.

The soil is a gravelly gray silt loam becoming yellowish a few inches below the surface. The amount of red increases downward so that the subsoil is usually a deep red. The percentage of stone increases downward. The more hilly the land, the more stony it is as a rule. On the slopes of the shallow valleys where they are steep the soil becomes in places quite stony.

One of the more persistent characteristics of this soil is the yellow color of the top part of the subsoil. Whenever that is exposed in ditches or on the roots of upturned trees it is very noticeable. This passes downward to a red stony clay subsoil within from 6 inches to 5 feet. On the gently rolling uplands the amount of stone is not sufficient to interfere with cultivation. There is usually a small amount running from 4 inches to a foot in diameter. This is not sufficient, however, to make the expense of clearing it off prohibitive. The rest of the stony material is in the form of smallish gravel from two inches in diameter down. This is all angular material. None of it is waterworn material. It has been left in its present place by the decomposition of the limestone rocks in which it formerly occurred.

In localities where there is no gravel in the gray soil layer the top of the gravelly part of the subsoil is a rather sharp line. In some localities this is rather hard, due apparently to cementation by lime. This kind of hardpan seems to be local merely and not to extend under the whole area of this soil. The greater abundance of stony material in the subsoil than in the soil causes the former to seem harder, when being dug into, than it really is. Farmers encounter this in wells, ponds, postholes and elsewhere and call it hardpan. It seems to be cemented into a true impervious hardpan locally only, and in small areas.

Until within the last fifty years practically the whole of the area of this soil consisted of grass covered plains with isolated black jack trees or clumps of such trees. These older trees are still standing in many places on the uncleared land but the space between the large trees is no longer covered with grass. It is a thicket of young saplings, chiefly black jack and post oak.

There are no permanently flowing water courses within the area of this soil. It lies on a watershed so that all its drainage lines are small though a few of them drain large areas. These latter have no permanent stream along them owing to the porous character of the soil and the rock beneath it. The water soaks readily into the soil and thence into the rock and seeks an outlet to the larger streams by springs. A relatively small part of the rainfall reaches the main river

by surface streams. The channels in all the valleys in this region are dry the greater part of the year, probably about eleven months of the twelve. Small pools lie in the channels in places a considerable part of the year but they are isolated from each other.

On the whole, probably about one-half of the area of this soil is now in cultivation, along the railways a somewhat larger proportion. The less stony and the smoother portions have been selected so far for cultivation. There are still uncultivated, however, considerable areas of a fair quality of this land. It is being cleared somewhat, but the rate at which new land is being put into cultivation, cannot be described as rapid. There is very little, if any, government land left in this soil area. Some of it, however, is still held in large tracts by non-resident owners.

This is not a soil of great fertility. It has, however, a good physical character, the country in which it occurs is relatively smooth, rendering it possible to handle it in large bodies and its supply of mineral fertility is moderately good. Its phosphorous supply is considerably below the standard for a rich soil, but is sufficient to produce fair crops until more can be supplied artificially. The greatest need of this soil is nitrogen and humus. The next greatest need is good thorough plowing and a general cleaning up of loose stones on the fields so that thorough cultivation can be done easily. For the present the growth of clover and cowpeas cannot be too strongly urged. More live stock farming will follow. The soil, while not rich, has good possibilities when handled with sufficient intelligence and capital. Like every other part of the Ozark region it is not the place for a man who has no capital to start with if he expects to do more than make a living.

Physical analyses of several samples from this soil gave 15 to 25 per cent of sand, 45 to 55 per cent of silt, and 10 to 15 per cent of clay. In the subsoil the per cent of clay ran up to 30 in one or two cases, though the other constituents did not vary so much.

The percentage of silt and clay is high making it a soil on which grass ought to thrive. The principal things needed for this are abundant humus and more nitrogen.

The crops now grown on it are chiefly wheat and corn. The yield of corn is about 25 bushels, and of wheat, where it is not fertilized, about 8 to 10 bushels.

The local water supply is from wells and ponds. Water is got in wells at varying depths, but a large supply cannot usually be obtained at a depth of less than one hundred feet.

The Post Oak Silt.

This is the soil of the post oak flats of the region. While the black jack soils occur chiefly on the Osage-Gasconade watershed, these occur on the Gasconade-White river watershed, and on the ridges between the main tributaries of the Gasconade. The largest areas occur in Texas county on the broad ridges between the Gasconade river and Roubidoux creek, between Roubidoux creek and Big Piney, and on the ridge east of Big Piney. Some of these belts extend southward to the main ridge. It occurs also in small areas scattered over the whole area of Lebanon soils. Wherever a flat topped ridge is found, or a flat portion of a ridge, this soil occurs. A typical area lies in the vicinity of Fowler, Texas county, and another near Dykes. The latter extends in a long narrow belt northward from Dykes to the Gasconade river. Considerable areas occur in Wright, in Webster, southeastern Laclede and southern Pulaski counties.

The timber growth is almost entirely post oak. Over much of it the virgin growth has never been cut. There is usually only a relatively small amount of underbrush. A considerable proportion of the trees are large, reaching a diameter of 12 inches or more. The growth is too thick for grass, although it is not usually brushy. Where the original growth of timber has been cut off within the last 25 years, the land, unless it is cultivated, is now covered with a dense growth of post oak saplings.

There is very little tree growth of any other kind associated with become a tough sticky bluish clay. On the more rolling areas it is some black jack and black oak.

The soil is a silt usually almost free of stone. The percentage of silt is about 60 and that of clay 12 to 15. It is, therefore, a fine-grained soil. It is gray in color down to 6 to 10 inches, becoming yellowish or bluish or gray below. On the typical flats, if the stone-free silt layer is rather thick, there is a tendency for the subsoil to become a tough sticky bluish clay. On the more rolling areas it is yellowish to brownish.

At a depth varying from six inches, or less, to three feet or more, usually about 14 inches, a harder, more stony substratum is encountered. The hardness and amount of stone is variable. In other places it is softer, though usually it is much more difficult to bore into this than the silt above. It is often hard even when the stones are small in size and few in number. The finer material among the stones is a brownish to yellowish silt or clay mixed with spots of tough, hard gray clay or silt. These latter do not cut easily and come up on the augur as hard or tough lumps. Whenever the stony layer is struck the subsoil is stony in varying proportions thence downward. It is

the ordinary residuary soil of the region. On the edges of the post oak flats where they break off into rougher land this stony layer is exposed because of the erosion of the overlying silt layer.

The top of the stony layer is sometimes cemented with iron or lime and thus converted into a hard pan. In such cases the soil layer is apt to be either too wet or too dry. It becomes thoroughly saturated during wet weather but dries out rapidly and cannot draw a sufficient amount of moisture from below to keep up its supply.

Probably not more than 30 to 40 per cent of this land is in cultivation. A considerable portion of it lies at a considerable distance from the railway and for this reason is not much in demand for farming. Of the land in the Ozark region sufficiently free of stone to be cultivated with fair satisfaction, the post oak flats, although nearer stone-free than any other, are considered the poorest. There is no crop that will grow well on them, timothy being about the best of the ordinary farm crops. Corn rarely produces, without fertilizer, more than 20 bushels and when the land becomes worn it is less. Clover does not grow well but cowpeas grow with considerable success. This is probably by far the most profitable crop that can be grown on this land. Where the stony layer beneath the silt is cemented or made relatively impervious to water this soil will be a difficult one to improve. The problem is a greater one than with many of the other soils where the main thing to do at first is to get the stone off. When it is got into a condition so that it can be well cultivated it can be improved. The post oak flats have the problem of a tighter subsoil. The growth of deep rooted plants like cowpeas and clovers will help and it is probable that the growth of these crops is the most feasible method of improvement available at present for these soils.

The Post Oak Glade Soil.

This is a shallow soil usually but little more than three feet down to the solid limestone and often much less. The surface is gray to black and the subsoil varies from yellowish, through brown, tints to deep red. Where it is stony the percentage of stone is large, the stones are white, hard, undecomposed and angular. The growth is scrubby post oak. It gradually changes into the black oak type as the solid rock becomes covered with a deeper layer of soil and the stones in the soil become more decomposed and more broken up. It occurs on hillsides where the limestone ledges outcrop abundantly. In wet weather it is apt to be too wet on account of the water being retained in the soil by the limestone bed beneath it. It dries out rapidly also. Where deep enough not to be affected by this it is a fairly good soil. A physical analysis of samples in Texas and Pulaski counties gave

an average of 40 per cent of clay, 35 per cent of silt and 15 per cent of sand.

It does not occur anywhere in large areas. It has a wide distribution however, but always in small areas, often of less than an acre and from this up to several acres, never running into square mile areas. A local phase of this soil is found in the heads of wide open shallow hollows, on gentle slopes, and in other faint depressions occurring in many parts of the Lebanon region. The soil is gravelly or stone-free and black in color down to a depth of a foot or more. Below that depth it becomes gray, bluish, yellowish, brownish or reddish.

The surface of these basins is often covered with low mounds 2 to 4 feet high and 8 to 20 feet in diameter. The post oaks growing in such places are small and grow, usually, in groups. This soil is known by the farmers as black limestone land. It is a fertile soil but cannot stand prolonged droughts as a rule. A physical analysis of a single sample from Texas county gave 18 per cent of clay, 46 per cent of silt and 30 per cent of sand in the soil and 36 per cent of clay, 40 per cent of silt and 15 per cent of sand in the subsoil.

The Vienna Soils.

Distribution and Topography.

This is the last of the important groups of upland soils in the Ozark plateau. The soils range from very stony to stone-free soils and from gray to black in color.

This soil lies at a lower elevation than the Lebanon soils. The latter lie on the areas of the old plateaus that have not yet been cut into deep valleys by the creeks, while the Vienna soils lie on the high bench lands along the main rivers of the plateau region.

These benches do not lie at exactly the same level everywhere. The elevation is determined chiefly by the size of the stream and the position on the stream. As a rule they are lowest, or in other words lie farthest below the plateau on the Gasconade and Osage rivers and higher in the smaller streams, being highest at their heads.

Along all the rivers and creeks there are two strips of Vienna soils, one on each side of the present valley. The two strips are parts of one and the same thing separated into two parts by the valley. The width of the whole bench belt from one side across the valley to the other varies widely. On the Gasconade it varies from a few miles up to about 15. On the smaller streams it is narrower. Within the Osage river basin, however, it is wide, occupying the greater part of the country, especially on the south side of the basin, reducing the Lebanon plateau soil areas to small patches along the main water-

shed. North of the latitude of Vienna, there are practically no areas of plateau soils. In this region, however, the Vienna soil benches have been extensively cut up by the many valleys of the existing drainage system so that while the total width and area of the Vienna benches is great the soils made by modern erosion within these benches occupy a large part of the areas. Nevertheless considerable areas of Vienna bench soils occur, especially in Miller and Maries counties.

Although the Vienna benches are remnants of areas that were at one time either level or not very strongly rolling, there is at the present time very little level land on them. A considerably smaller proportion of the area is level than that of the Lebanon area. It has been cut up by the existing streams into a hilly area, being more hilly on the outer and inner borders of each belt and smoother along its middle. On the inner border of each belt (each half of the old valley), the existing creek valleys and ravines are more numerous deeper and steeper while on the outer border there are the hills that bordered the old valley lying between it and the smoother Lebanon plateau areas. As a whole, therefore, the Vienna soils occur in a hilly to strongly rolling country.

Timber.

Like most of the Ozark upland, this region was either prairie or open grass-covered woods up to the middle of the nineteenth century. One small area in Texas county still bears witness in its name, Ellis Prairie, to its former condition. The whole of the region is, except where cleared for cultivation, at the present time covered with timber. The trees are mainly Black and Red Oaks; the former predominating. In fact this area might be called the Black Oak area of the Central Ozark region, just as the Lebanon area is the Black Jack Post Oak area.

There are a few small areas in the Vienna soils covered with Black Jacks and still fewer where Post Oaks predominate. The latter occur, however, as occasional trees in the Black Oak areas and White Oaks occur also. On the well-drained nearly stone-free soils with abundant lime, Walnut, Elm and other softwood trees occur.

The Soils in General.

As stated above the soils are stony to stone-free silt loams, the percentage of stones varying widely. On the basis of roughness or smoothness of the country each belt has three strips or subdivisions; an outer strip of hilly country lying next to the Lebanon soil areas, a middle belt that is smoother and an inner belt that is rougher lying alongside the belt of Reynolds soils to be described later. The latter strip is

usually somewhat more stony than the others while the outer strip has a more shallow soil as a rule and a more scrubby growth of timber.

As a rule the Vienna soils within the drainage area of White river are more stony than north of it. In fact there is a gradual decrease in percentage of stones northward over the whole area, being fewer in the northern part of the area than elsewhere. The color of the soil is gray and of the subsoil red. The proportion of stones is about the same in both soil and subsoil except locally. The percentage varies from almost nothing in a few places to 80 or 90 per cent in the inner hilly strip of the belts. There are four main types of soil, they are the Black Oak gravelly, the Post Oak silt, the Black Jack gravelly and the Black Oak Stony soils.

The Post Oak Silt Soil.

The Post Oak Silt soil exists only on the flat areas. It is much like the Post Oak Flat soil of the Lebanon area. Like that also it is always underlain by a stony subsoil, the top part of which is sometimes cemented into a hardpan. The thickness of soil down to this stony layer varies, but is rarely more than 18 inches. These soils as a whole are usually considered stronger than the Post Oak flat soils of the Lebanon group, although they are more difficult to cultivate and a much larger proportion of the area is wholly unfit for cultivation on account of the large percentage of stone in the soil as well as the rough character of the country. This is generally true of all the soil types of the Vienna group when compared with the corresponding soil of the Lebanon group. The Vienna soils are more stony and occur on a rougher topography than the Lebanon soils yet where they are not too stony to cultivate they are considered more productive than the latter.

There are several things which may aid in producing this result. The rocks from which the Vienna soils are derived are somewhat purer, more crystalline limestones and possibly have a lower percentage of magnesia than those from which the Lebanon soils are derived. The Lebanon soils may not be wholly residuary also. The Lebanon soils are older and have been subjected to leaching for a longer period of time than have the Vienna soils. The Vienna soils occur in a more rolling country where soil creep on the slopes is more universal than on flat areas like those of the Lebanon soils. This tends to keep the subsoil more broken up and corrects what tendency there may be toward the formation of closely cemented layers or hardpans.

A much smaller proportion of these soils is under cultivation than of the Lebanon soil.

The Black Oak Gravelly Soil.

This is essentially like the same type in the Lebanon group. It seems to have, as a whole, a deeper red color in the subsoil and supports a larger proportion of hickory trees and of hazel and sumac undergrowth than does the corresponding Lebanon type. The smoother, gravelly Black Oak land of the Vienna group is, in many parts of the Ozark region, called "Hickory Bench land."

The Black-Jack Gravelly Soil.

This soil has a limited area. The largest body of it occurs in Franklin township, in the Cobbs creek country of Laclede county. It is somewhat dryer, more gravelly and paler in color than the corresponding type in the Lebanon group. On that account it is not so good a soil for all crops as the latter.

The Black Oak Stony Soil.

This soil in the Vienna area does not differ essentially from the Reynolds soil, especially when the latter occurs on stony slopes.

Crops.

The crops that are actually grown on these soils do not differ greatly from those grown on the Lebanon soils though the land is better adapted to corn and clover than the latter. The Black Oak soils in the Ozark region, wherever they occur, are natural clover soils. It grows no better, however, on the Post Oak soils of the Vienna area than on the Post Oak flats of the Lebanon area. Cowpeas also grow equally as well on these soils as elsewhere.

The yield of all crops is low. This is due chiefly to a lack of nitrogen in the soil. The phosphorus content is low also but the factor that limits production at the present time is nitrogen. The percentage of vegetable matter is low and becoming lower. It was low to begin with for the same reason that it was low everywhere in the Ozark region. The open porous nature of the soil permits its rapid destruction under cultivation. The future is dependent upon more live stock, more forage crops, less grain farming, less cultivation, more vegetable matter plowed under. When the vegetable matter in the soil has been greatly increased then the addition of phosphorus in some form will still further increase the yield, especially of grain.

The average of several physical analyses of the Black Oak soils in the area of this group gave 12 per cent of clay, 60 per cent of silt and 20 per cent of sand. The sand in most of these cases probably consists of very finely broken chert rather than grains of quartz, though these sandstones occur in the formations.

The Salem Soils.

Distribution.

This group of soils occupies an area rather than a belt, occurring on the eastern side of the central part of the Plateau region. They occur as a continuous body of soils only on top of the plateau.

The Rocks.

The formation underlying these soils and from which they were derived outcrops in a narrow belt along most of the large streams of the Plateau region and elsewhere but except the area colored for Salem soils on the soil map the outcrop is narrow and occurs on hillsides where the soil is incorporated with debris from overlying limestones, thus losing its character as a sandstone soil.

Soil.

The soils are stony sands, sandy clays and loams with varying proportions of sand and stone and clay. They are residuary soils derived from the disintegration of a sandstone. The rock varies somewhat in character but is usually a rather pure quartz sandstone cemented with iron and holding a relatively small percentage of clay. Over a large part of the area in which this rock has determined the character of the soil the sandstone has weathered completely and the products of its weathering have become more or less incorporated with the products of the weathering of the underlying limestone. The sandy soil in such cases becomes orgillaceous and stony, though it is never stony to excess.

Topography.

The topography of the area in which these soils occur is that of a plateau dissected by shallow valleys. The local relief is but little more than 100 feet over most of the area. The streams all flow northward and owing to the great distance that they must traverse before reaching a large stream like the Mississippi and to their winding course they are unable to cut deep into the country. The valley sides are sloping, rarely too steep for cultivation. The valley bottoms are narrow. There is very little flat upland. It is, in short, a plateau dissected with shallow valleys. There are practically no permanent streams in the area. The valleys have stream channels in them but they are dry except during excessive rains. The drainage channels are all of them the upper parts of streams and are all small. As soon as enough of the small drainage channels have united to form one large enough and deep enough to hold a perennial stream it has cut beneath the sandstone level into the underlying limestone and into another group of soils.

There is very little of the area of the Salem soils that has too rough a topography for cultivation.

Timber.

Until half a century ago the whole of this area was a prairie but not wholly treeless. It was set with occasional large trees or in places was open woods. The timber was nowhere, except along the bottoms, too thick to hinder the growth of grass. At the present time every spot not in cultivation is covered with a growth of saplings and brush. On the sandier portions this growth is almost exclusively Black Jack. Where there is a moderate percentage of clay Post Oak replaces part of the Black Jack and on the stony portions where the subsoil is the stony clay derived from the underlying limestones, Black Oak becomes common. The original open woods growth was chiefly Black Jack.

The Soils in General.

The soil types in this region, unlike those in almost any other group of the Ozark region, depend wholly on variations in character of the rock from which they were derived, not on the topography, that being practically uniform over the whole region. The soils are sandy loams. The types varying from each other in the percentages of clay and sand and in the character of the subsoil. There are two main soils. In both the soil is derived from the decomposition of the sandstone. In one of them the subsoil also is derived from the same rock. In the other the soil is derived from the sandstone, while the subsoil is the stony clay of the underlying limestones. This latter type occurs around the northeastern and southern borders of the region and along some of the larger valleys. The other occurs in the interior of the area. The distribution of the different types of interior soils is not yet determined definitely. There is an apparent increase in sandy character southward and eastward. The soils are all gray to brownish or yellowish in color with a subsoil of somewhat deeper red color. The grayness of the soil is a function of the amount of leaching to which it has been subjected. It is everywhere low in organic matter and is inclined to wash where the slopes are only moderately steep. The subsoil is free from hardpan and has in most places sufficient clay to enable it to hold a fair quantity of water. The soil is light, has good tilth where well cared for and cultivates easily. The proportions of sand silt and clay from several samples taken at various places are as follows: Sand 25 to 40 per cent, silt 45 to 55 per cent, clay 8 to 20 per cent in the soil and sand 25 to 40 per cent, silt 35 to 45 per cent and clay 20 to 30 per cent in the

subsoil. About thirty-five per cent of the area of these soils is in cultivation. The cultivated area extends along all the valleys spreading out over the adjacent slopes but not often extending far into the upland. There are some isolated areas of the highest uplands that are cultivated but the proportion to the total area is small. The cultivated area is the valley and valley slope area. The ridges are still in timber. Very little new land is being placed in cultivation. So far as agricultural improvement is concerned this area is at about a standstill or is gong backward. Probably as much or more land that was formerly cultivated is being turned out as there is of new land being put into cultivation. One reason for this is the natural thinness of the soil. Yet this is not the only reason. It is partly due to the fact that owing to the decline in iron mining the country has been decreasing in population. On account also of the iron mining and its attendant wood cutting and charcoal industry agriculture has never been considered the chief industry of the area. It has stood second in the minds of the people. The soil is thin but it is not hopeless. It is a soil that will respond quickly to good treatment. It cannot be made into a good soil in one season nor without capital and it will always be a somewhat expensive soil to handle on account of its somewhat leachy character. This, however, is not excessive. Its tendency to wash and the moderate amount of mineral fertility that it contains are factors that must be considered. The cheapness of the land and the low cost of living will compensate to a considerable degree for these things. Handled in rather large bodies with intelligence, industry and capital it can be made to produce paying crops. It will grow clover fairly well but probably the sandier soils need lime. Corn on the uplands does not yield more than 25 bushels, except where special conditions obtain and wheat yields 6 to 12 bushels. The quality is good, however, especially on the bottom lands. Very little clover is grown. Timothy is grown for hay but the yield is small. In fact the yield of all crops is low on upland soil that has been in cultivation longer than ten years. The limit of production is set by the deficiency of nitrogen, which can be returned to the land without money cost by the growth of clover and cowpeas.

THE OZARK CENTER SOILS.

General Character of the Area.

The Ozark center as here defined is not in the geographical center of the Ozark region. It is, however, the structural center of the region. It is the area cone or center around which are arranged with greater or less regularity the belts of soil that have been described

already, especially those of the Ozark Border and around which curve those that make up the Ozark Center area itself. It is the part that was bowed up the highest when the bowing up of the rocks took place, though it is not now the highest area of the Ozark region. It has been worn off more therefore than any other part of the Ozark region, since it was originally the highest part but can no longer maintain that position. This has been brought about by wear from the top not by down bending or down sinking of this part of the region. It is this part of the Ozarks therefore where wearing has gone deepest and exposed the oldest rocks. This area therefore is differentiated from the others partly because it is made up of older rocks than any others and therefore of different rocks. It contains the very oldest rocks that are to be found at the surface of the ground anywhere in the Ozarks. In other parts of the region these very oldest rocks are hundreds or thousands of feet beneath the surface.

This area differs also from the others in topography. While it is not the highest area as a whole yet it has the highest point within the state. It contains the group of isolated rounded mountains known as the St. Francis mountains. It contains also a large area of very badly cut up country, and a very small proportion of high smooth plateau. The ridges and watersheds are narrow. It is an area of thoroughly dissected or cut up country. It also contains the only areas in the state of low basins surrounded by high country—a kind of intermontane basin. It also contains the only large areas of pine timber that are now standing or has ever grown up in Missouri since white man knew it. It was more completely covered by forest growth when first seen by white man, even outside the pine area, than the other areas of the Ozarks. Its timber, where it has not been cut in the last half century, is much larger than elsewhere and there is a much smaller proportion of young growth and brush. Its differences therefore are sufficient to differentiate it thoroughly from the rest of the Ozark region.

Since its differentiation is based on its physical characteristics rather than on its geographic position it follows that wherever the same series of events has taken place on the same kind of material we shall have similar regions developed—or subordinate centers. There is one such real or true subordinate center, true in every respect, lying in Camden and adjoining counties and a second area, or subordinate center of a lower degree, lying in Douglass and Ozark counties.

Topography.

As stated above this area, taken as a whole, is the roughest of the soil areas in the state. This is due chiefly to the great number and

the depth of its valleys. In all the other areas containing a single soil group there is more or less smooth high country or flat-topped ridges or else of gently undulating land making up no small proportion of the whole. In the Ozark Center these are practically absent. In the greater part of this region practically the only level land is the alluvium which lies in narrow strips along the main streams. A level or smooth upland of more than a very few acres in extent is of rare occurrence. The only areas of relatively smooth country within the Ozark Center are the low basins that occur in the eastern part of the region. These have a rolling to slightly hilly topography surrounded by higher country.

Another division of the topography of the region is the area of rounded hills, some of them higher than the dissected plateau portion of the region and some lower. Occasionally they are alone, surrounded only by other phases of the topography and at other times they are assembled into groups. Each hill however is usually rather isolated, except at its base. A group of them does not form long, level topped or even topped ridges. The existing streams have not shaped these hills from the existing upland by erosion but they were fashioned by erosion of long vanished streams and lay buried under the present upland until the existing streams by their work uncovered them. Many others exist not yet uncovered. The tops only of some have been uncovered.

The three kinds of topography therefore are: (1) the thoroughly and rather deeply dissected plateau; (2) the lower undulating basins and (3) the region of rounded hills.

Timber.

The timber growth in the Ozark Center region consists of four dominant trees with the usual amount of brush and shrubs. The four dominant trees are Black, Red and White Oaks and Pine. There was originally more or less pine scattered over the whole area though it was more abundant in the southern part. Pine does not grow anywhere to the exclusion of all other trees and in most places it constitutes not more than half the total timber. It grows chiefly on the southerly slopes and on the ridge tops, rarely on the northerly slopes. The Black oak grows on the dry stony ridge tops and on the southerly slopes while the white and red oaks grow almost exclusively on the northerly slopes. The easterly and westerly slopes maintain a more or less even balance of tree growth among the several varieties. In the low land basins above referred to red oaks predominate with considerable Walnut, Elm, Hackberry and other trees which grow on fertile land. Post oak is not unknown but it occupies a very subordinate position in the whole Ozark Center.

The Soils in General.

The differentiation of the Ozark Center into groups of soil types is based chiefly on the kind of rock underlying the area of each group. There are four groups, the Reynolds, St. Francois, Lamotte and Fredericktown. The soils of each group are underlaid by a different rock from that of any other group. The Reynolds group is underlaid by a Limestone which has a rather large proportion of flint. The St. Francois group is underlaid by granites, porphyries and other igneous or volcanic rocks. The LaMotte is underlaid by a sandstone and the Fredericktown group by a limestone rather pure and practically free from flint. Each group of soils occurs in a region with a topography more or less distinct from that of any other. With one exception this topographic distinction is a pronounced one.

The Reynolds Soils.

Distribution.

This group of soils covers by far the largest area of any of the Ozark Center groups. It covers practically all of Shannon, Reynolds, Carter and Camden counties; large areas in Iron, Wayne, Crawford, Washington and Madison counties and small areas in other counties. Its area is several times larger than the combined areas of all the other groups associated with it in the Ozark Center.

The Rocks.

It is underlaid by a limestone containing a great deal of flint or chert. At the top of the formation there is usually a sandstone also, but it is not usually thick enough to have a marked effect on the character of the soil. Immediately below the sandstone or in the upper part of the limestone there is a great deal of flint. It often occurs in beds of practically pure flint ten feet and more in thickness. Since flint does not disintegrate into soil but merely breaks up and remains in the soil as stone fragments, it furnishes a great deal of stone to the soil where it is, as in this region, abundant in the rocks. There are other beds of flint lower down in the formation and these increase the stony nature of the soil. The middle portion of this thick limestone making up these soils is nearly free of flint, however, so that wherever it outcrops and the soil of an area is derived from it without intermixture from above it is about free from stones. The limestone, aside from the flint occurring in it, is a rather pure, coarse grained and usually crystalline rock. It has a relatively small amount of clay impurity so that on decomposition a small amount of soil is formed. This makes the soil more stony by increasing the relative amount of stone in it.

Topography.

This is a plateau thoroughly cut up with streams. As a whole it is the most intricately dissected of any of the soil areas in the Ozark region. It is almost one uninterrupted series of narrow branching valleys and sharp ridges. The occurrence of even small areas of smooth upland are so infrequent as to be practically negligible. The only areas large enough for even a small farm are in Crawford and Dent counties where the Reynolds soils are not typical on account of being mixed with sand and clay from formations that originally overlay this part of the Ozark center. The tillable area of this group of soils is small and will always remain so on account of the roughness of the topography. The tillable soils are chiefly in the river and creek bottoms.

This is the area of the state that should be devoted to the growth of timber. Its topography is too rough to make agriculture, except in the valleys, profitable. Its soil is too stony to be cheaply utilized for growing farm crops even if its topography was more favorable to agriculture. Its soil, however, is strong enough to support timber that has commercial value and the soil layer is thick enough to permit the growth of such timber. In other words the limit to agricultural development in the region is not determined by a lack of fertility in the soil but in the difficulty of utilizing it for growing farm crops. The timber has long served as the basis of a small manufacturing industry and with proper methods of conservation it could long continue to serve the same purpose.

Timber.

The tree growth is Black, Red and White Oak and Pine with a small amount of Post Oak, especially in Crawford and Dent counties. Pine grows or has grown in nearly all the counties of the main area but it was most abundant in Reynolds, Shannon and Carter counties. The main area extended from these counties over into most of the others. It never grew in any part of the Camden county sub-area of the Reynolds soils. Most of the pine has been cut.

White oak grows on the northerly slopes and most abundantly in Shannon, Reynolds, Crawford and Washington counties. A considerable part of this timber is still standing.

Black oak and Red oak are less valuable. They grow chiefly in the southern counties. Not a large part of this timber has been cut except locally. Large areas of it, however, are of little value except for local building material.

The Soil Types.

Sufficient has already been said about the rocks and topography to give a fair general idea of the soil conditions as a whole. They are all

residuary except the alluvium and vary from stone free silts or sandy silts to extremely stony silts.

There are four different kinds of soils in the area sufficiently distinct to merit recognition. They are the Reynolds stony loam, the Morgan gravelly loam, the Crawford silt and the Reynolds loam. The first three are upland soils, the last is the bottom land alluvium.

The Reynolds Stony Loam.

This is the dominant soil type of the region. It occurs in all the hilly parts and is almost everywhere forest covered. The timber is Pine, Black, Red and White Oak; Pine does not grow on any of the other types. The soil is derived from the disintegration of a very cherty crystalline limestone. It is gray in color, down to a depth of about a foot, then gradually changes through yellow and brown to a red subsoil. The fine material of the soil is clay silt and sand in about the proportions of 8 to 10, 55 to 75 and 10 to 25 respectively. It is open and porous and warm. The percentage of stone varies from 25 to 90. The stone may exist as small fragments of small gravel size or as fragments of several hundred pounds in weight. The subsoil has a higher percentage of clay and lower percentage of sand, has a deeper color and about the same proportion of stones. There is rarely any suggestion of a hard pan. Its percentage of nitrogen and phosphoric acid is low and potash is high. The lime percentage varies, usually it is low, however.

On account of the roughness of the country in which this soil occurs very little of it has been put in cultivation. It is too steep to plow profitably in most places and can be utilized only for pasture. Wherever there is enough soil for plants to establish themselves and to furnish moisture clover grows luxuriantly. It is a natural clover soil except where it is too stony or too much exposed to the sun. The best places for the establishment of clover pastures are on the northwardly and eastwardly facing slopes. These slopes have no pines but are covered with Red and White oaks and occasional soft wood timbers. On these clover and orchard grass will grow as soon as the timber is cleared and blue grass will take hold when the soil has accumulated sufficient humus. This will rarely take place on the southwardly sloping hillsides. They are too much exposed to the direct rays of the August sun. The humus is soon burned out and the soil dries out rapidly. These slopes are adapted to the growth of pine timber better than anything else that has any value to man. Grain crops are not grown to any appreciable extent.

This soil can never support a prosperous agriculture. It can be utilized only in connection with some of the other types, particularly the Reynolds loam. It can supply supplemental pasture land and tim-

ber land to the latter. The farmer who owns a good bottom land farm finds it convenient to own some of the stony hill land for pasture and for the growth of building material. Where other conditions are equal this combination gives the farmer a great advantage over the prairie farmer.

To sum up the whole matter in one sentence: The Reynolds Stony Loam is not an agricultural soil.

The Morgan Gravelly Loam.

This soil is derived from the middle beds of the great limestone formation of the Reynolds group of soils. This part of the formation is almost free from chert and consists of massive beds of crystalline limestone. When it disintegrates it forms a stone-free silt.

It does not occur in a large body anywhere within the area. Its chief occurrence is on the hillsides within the area of the Reynolds Stony Loam and in bodies of relatively few acres in a place. It is rarely entirely free from stone. They drift down onto it from higher areas of stony loam but are usually broken up into rather small fragments making a gravelly rather than stony soil. It occurs in larger bodies in Crawford and Washington counties than elsewhere, particularly in eastern and southeast Crawford and southwestern Washington counties. It occurs also in Morgan county and to a slight extent in St. Francois and Iron.

It is gray to brownish or reddish in color gradually changing downward to a reddish subsoil. The latter is usually deeper red in color than that of the stony loam. The fine material of the soil, in this case making up most of it, has a higher percentage of clay and a lower percentage of sand than the stony loam.

Its deficiencies are nitrogen and phosphoric acid. Its physical analysis shows a favorable physical character. The small percentage of stones does not hinder its cultivation seriously. On account of this, however, and its almost universal occurrence on hillsides it washes badly where cultivated in grain crops continuously, especially where the humus has been about all burned out of it.

While this soil, under proper management, makes a fairly good grain soil its tendency to wash reduces its value for that purpose. As a clover soil it is equal to the best part of the stony loam and on account of its greater proportion of fine material and cooler nature it is a better grass soil. Its occurrence in small areas or patches makes it an expensive soil to cultivate. When put into pasture land or clover meadow owned along with bottom land the combination is a good one. The gravelly loam makes excellent and cheap pasture or clover meadow while the bottom lands are excellent grain lands. Such a combination

is especially adapted to stock farming. The region abounds in springs of good water also. It is not the place for the 40 acre farmer, however. It must be owned in bodies of considerable size and must be handled by farmers with sufficient capital behind them. There is no market in the region for such crops as a man must grow on a 40 acre farm in order to support a family. It is too far, in most localities, from the railway to favor the development of the dairy, fruit or poultry industries. It is especially adapted to sheep and hog farming and the growth of stock cattle. It can probably never become a region where cattle feeding on a large scale can be carried on because of the very limited area of corn land.

The Crawford Silt.

This is the soil of the flat uplands of this region wherever they occur. It occurs most abundantly in southern Crawford county, east of the Meramec river and its drainage area. The type occurs in Dent county also and in small strips along the tops of the ridges in nearly all the other counties.

It is a gray to yellowish sandy silt to clay silt graduating downward into a mottled to bluish clay or silty clay. There is a general absence of deep color in the soil or subsoil. The proportion of sand varies greatly. In some localities remnants of the sandstone underlying the salem soil still exist. In such places the soil is sandy. In other places the sand is very small in quantity and the soil becomes almost a blue clay in character. This occurs naturally only in the flattest places or in sags. The finer parts of the soil have come from originally higher rock or else is a remnant of a silt deposit that at one time covered the whole of the Ozark region, existing at the present time only on the highest flat portions like this area or that of the Lebanon silt loam area. Its lack of color is probably largely due to leaching. It is the oldest soil of the region and has been subjected to leaching for the greatest length of time. The leaching has affected not only the coloring matter but all the soluble constituents of the soil. We have no analyses of a typical sample of this soil but its probable origin, present conditions and crops indicate that the most important deficiency in its mineral constituents is lime. It is especially deficient in that and until that is supplied it cannot be built up rapidly. Clovers do not grow on it very well. Its other deficiencies most urgently needing correction are humus and nitrogen. These deficiencies can be supplied in the same way as recommended for other soils of similar deficiencies. Clovers will not grow here advantageously. Cowpeas will, however, and they should be one of the constant members of any system of rotation adopted for these soils. Lime, where it is deficient, will have to be carted onto the land. It cannot be grown.

The timber growth on this soil is Post Oak, Black Oak and Black Jack with occasional Hickory and other hard wood trees. The trees are all small, not approaching the size of the trees on the other types of soil of the group. It is a scrub oak region.

The water supply problem in the area of this soil is different from that of the other types. There are no surface streams and no springs. Water must be obtained in wells and in reservoirs.

The crops grown are essentially the same as those grown on the other soils. The yields are very low, however. Fruit growing has received some attention and fruit trees do fairly well. No large area however has been set in trees.

Probably about 15 to 20 per cent of this soil is in cultivation. The advantages that it possesses over the other types already described is the smoothness of the country in which it occurs. Its disadvantages are its natural infertility, and its inconvenient water supply. It is not a hopeless soil but it is one that will cost rather heavily by the time it is put into good condition.

The Reynolds Loam.

This is the bottom land soil of the region. It occurs along all the river and larger creek valleys in strips of varying width rarely reaching more than three-eighths of a mile. The average width is considerably less than a quarter of a mile. The channels of the creeks change from place to place in the bottoms during floods. This reduces the width of bottom land available for cultivation considerably. In time these streams may be controlled but not in the near future. The areas are somewhat patchy also because of the wandering of the creek or river channel from one side of the valley to the other. The land is not perfectly level. There are low terraces in all the valleys and the soils included in this type extend up the more gentle neighboring slopes to a greater or less distance. The division line between the true alluvium and the residuary soils of the gravelly loam, is not sharp. True water laid alluvium extends up the slopes somewhat and above that is a zone of soil resulting from the wash of fine material from the higher slopes. All of the soil of this character is included in this type. In detailed mapping they would be separated.

The only timber left standing on the bottom lands consists of strips along the streams and covering the area that is overflowed by moderately high water.

This is either very low and rich land or else nothing but gravel bars. The trees are Sycamore, Elm, Hackberry, several kinds of Hickory, Red Oak and White Oak, Walnut, Burr Oak and Pin Oak. Cotton-wood rarely occurs, Linden occasionally, Birch very rarely and

Black Gum rather common in the small, high, dry, very gravelly valleys.

The soil varies from a black stone-free loam to a light gray gravelly to stony clay loam. The true alluvium is usually stone-free and dark in color, though occasionally lighter colored to reddish. These, however, on the smaller creeks do not by any means occupy the whole width of the valley floor. Every tributary small hollow opening from the adjacent hills brings small stones, clay and silt during heavy rains and spreads them out on the main valley floor around where it opens into it in the form of an alluvial fan, built up higher at the mouth of the hollow and sloping off in all directions from this. This buries the alluvium of the main valley under this material. It may be quite stony or merely gravelly. It is rarely free from stone. The greater the proportion of stone, the higher it is built up at the mouth of the hollow and the steeper its slope down to the level of the main valley alluvium. If the hollows are small they do not have a channel across the bottom into the main creek but the water spreads out over this fan of material that it has deposited, sinks into it and gradually seeps through it and out onto and into the main bottom. This is apt to make a wettish strip in the main alluvium around the feather edge of the fan.

The main valley alluvium changes gradually downward to a gravelly and sandy clay and finally into a gravel bed or sand bed at depths varying from 5 to 20 feet. The fan of soil washed in by the small hollows continue uniform to the bottom of the fan material, below which comes the true alluvium of the main valley. The subsoils of the wash slopes gradually become either gravelly or more stony and pass into the unmodified red stony silts of the residuary soils of the region.

Occasionally there are terraces in the main valley with a gray stone free silt soil and a clay subsoil. This is a rather rare occurrence, however. Hardpan is of very rare occurrence in the alluvial soils. Occasionally the gravel layers may become cemented but such occurrences have not been met with.

The physical character of these soils is good. They are porous, warm, well-drained soils, not too stony to be easily cultivated and do not have enough clay to make them heavy. They dry out and warm up early in spring and promote rapid growth, both on account of their physical character and their protected position.

Their store of mineral fertility is greater than that of any of the upland soils. They are rarely badly deficient in lime, their potash content is high and their phosphorous content moderate. These minerals are being continually supplied to them by the seepage water from the adjacent hills.

Their supply of humus when first cleared is good. Forest fires did not run through these bottoms every autumn like it ran over the hill lands. The leaves and grass were left to decay and supply humus. Under cultivation, this is rather rapidly burned out. On account of the more luxuriant growth of vegetation on this soil it is not so rapidly exhausted as on the upland. Considerable straw and other waste furnish a moderate supply. This is not sufficient, however, to keep it up to the standard requirement. The amount is being gradually exhausted and is having its effect in decreased yield. This is, in practically every case, the cause of the decrease. The wearing out of the land is not due to the serious reduction of its mineral fertility but to the exhaustion of its humus.

This soil does not wash badly. Some of the steeper slopes will wash but the proportion of land injured in that way is not great. It is not a leachy soil. The percentage of clay is sufficient to retain the fertility put onto the land in manures or in moderate amounts of commercial fertilizer.

This is a grain and clover soil. The grains chiefly grown are corn and wheat. The yields of corn vary from 25 to 60 bushels and of wheat from 10 to 25. Clover catches easily and produces a good yield though it is not as extensively cultivated as it should be.

This is the soil that produces the agricultural products of the Reynolds area. Practically all of it is in cultivation and has been in cultivation for many years. It is the seat of many good farms and prosperous farmers. On account of the limited area of this land it is held at as high a figure or possibly a slightly higher figure than land of the same productive capacity in places where the whole body of tillable land is good.

The owner of a body of this land, however, is the wealthy man and to a certain extent the leader or one of the leaders in his community.

The small amount of tillable land and the large amount of vacant land give cheap pasture, cheap fuel, cheap building material for most purposes and abundant room. Life conditions are somewhat primitive but not necessarily less attractive.

The Fredericktown Soils.

Distribution.

This group of soils occurs in a number of separate basins in the eastern part of the Reynolds soils area. The soils are all residuary and are derived from limestone beds that are practically free from flint. This yields a stone-free soil except where fragments of the limestone

are found in it. It has no flint. There are two kinds of limestone underlying this soil. One is crystalline, massive, rather coarse-grained pure limestone or magnesium limestone. The other is a rather shaly, impure limestone containing considerable clay in its composition. The latter limestone is sometimes associated with thin beds of limy shale. Sandstone beds and beds of sandy limestone are of very rare occurrence.

Topography.

The topography of the areas in which these soils occur is a rolling to slightly hilly plain. There are basins also being surrounded by higher land on all sides. There is very little level land but there is also a relatively small amount of land that is too rough to cultivate.

Timber.

There is very little timber now standing on these soils. The most abundant tree is Red Oak. There is some White Oak, Post Oak, Elm, Walnut, Laurel Oak, Sycamore, Wild Cherry and other bottom land trees.

There is one large area and a great number of small, wholly or partially disconnected areas, in all about twenty in number. They are all alike in rock, soil, topography and relation to the surrounding country.

The Soil Types.

There are two kinds of upland soils in this region, both of which are probably groups of two or more types. There is also an alluvial type. The upland types are, (1) The Caledonia Brown Silt Loam, (2) the Bismarck Gray Silt Loam.

The Caledonia Brown Silt Loam.

This is a reddish, brownish, yellowish to grayish silt, to clayey silt soil free of flint with a deep red clay or silty clay subsoil. The thickness of the soil varies from a few inches to about a foot. There is no marked change or sharp boundary between soil and subsoil. There is a progressive increase in red color downward practically from the surface or from near the surface. There is no essential difference except in color, the clay content and the amount of humus. Analyses of several samples taken from widely separated places within these basins gave an average percentage of 23, 70 and 12 of clay, silt and sand respectively in the soil and of 30, 60, 10 per cent in the subsoil.

This soil occupies the center of each of the main basins. It occurs around Caledonia, at Belgrade, Farmington and southward to Libertyville, Fredericktown, Belleview, along the St. Francois river below Saco, around Patterson in Wayne County and on the Meramec river south of Sullivan. It is marked everywhere by its red color and by the growth of Walnut and Elm trees. It supports the growth of

some fine Red and Laurel Oak timber and scattering White Oak. Its topography is usually slightly more rolling than that in which the Bismarck Gray Silt Loam occurs. The limestone beds outcrop adundantly along the creeks in these areas. The depth of the soil layer is not so thick as that of most other types in the Ozark region.

It is the most productive of the two types of soil in these basins. Its store of mineral fertility is fairly good; it is warm and easily cultivated; is well drained but holds a considerable amount of capillary water ready to be delivered to plants. It is a grain and clover soil, being somewhat better adapted to wheat than to corn though it grows both of them successfully. It grows clover luxuriantly.

The yields of wheat vary from 15 to 20 bushels and of corn from 20 to 50 bushels per acre. Where it has been run in grain continuously for years the former yields rule. Its decreased yields are due to the exhaustion of the organic matter, the nitrogen and to a partial exhaustion of phosphorus. Bone meal sown with the wheat usually gives marked increase in the yield. Clover in the rotation gives excellent results. Not enough attention is paid to growing it, however.

The only other upland soils in the Ozark region that rank with this in productive capacity are the Perryville and the better part of the Springfield soils.

Practically all this land is in cultivation and has been cultivated for a long time. These basins were the first upland soils to be extensively cultivated in Missouri. This is partly due to their occurrence in mining regions and partly due to their fertility. They were occupied next after the Mississippi river bottom lands. This soil stands in much the same relation to the agricultural wealth of the counties of the Eastern Ozarks as does the alluvial soils to the area of the Reynolds soil group.

The Bismarck Gray Silt Loam.

This soil occurs around the borders of the basins in which this and the preceding type occurs as well as in isolated areas here and there within the basins.

It is, like the Caledona soil, nearly free from stones, though on its outer border where it lies adjacent to a stony soil of another series it contains some stone. It is gray in color with a yellowish to reddish subsoil. The paler character of the soil and subsoil when compared with the Caledonia soil is due partly to leaching and partly to a slight difference in character of rock from which the two soils are derived. It has been stated above that the limestones of these basins present two varieties, (1) a crystalline, rather coarse-grained variety, (2) a finer-grained, somewhat earthy to shaly variety. The Caledonia soil is derived chiefly from the former and the Bismarck soil from the latter. The

latter rock is the higher, geologically and occurs around the outer borders of the basins as a rule. Where the basins lie adjacent to an area of granite or porphyry, the gray character of the soil is due partly to the wash of soil from those areas.

When the limestone becomes shaly the soil is gray as elsewhere but the subsoil is much paler in color than elsewhere.

The surface of the areas where this soil usually occurs is usually undulating to slightly hilly, rarely rough enough to interfere with cultivation except locally. The timber growth is chiefly Red Oak with a small amount of white oak and some post oak on the flatter, partly leached areas.

This soil is not so productive as the Caledonia soil. It is easily cultivated however and where its humus supply is kept up it produces fair crops of corn and wheat. Clover does not do so well on it as on the Caledonia soil possibly because of the lack of lime and because of poor drainage. It is usually deficient in humus and therefore deficient also in nitrogen. It will produce fair crops of cowpeas on its thinnest parts.

It washes where it occurs on slopes but this is much more unusual than in the case of the Caledonia soil. The latter occurs along the drainage lines where it is more or less exposed to erosion and where its red color is, in fact, due to the continuous erosion from the surface of the top or leached portion of the soil. There is no sharp line separating the areas of these two kinds of soil. They graduate imperceptibly into each other.

The greater part of the area of the Bismarck soil is in cultivation, probably about 60%.

The Lamotte Soils.

General Distribution and Character.

This is a group of soils occurring in rather close association with the last two described. As a rule the country in which it occurs is a little higher than that in which those soils occur but is lower than that in which all other types that occur in its neighborhood occur. It lies adjacent to the areas of the Bismarck and Caledonia soils occupying therefore part of the basins in which they occur.

It is underlaid by a sandstone. It is the lowest and oldest sedimentary rock in the state. It occurs at the surface therefore only where the overlying rocks have been worn off. It lies immediately beneath the limestones from which the Caledonia and Bismarck soils have been derived. It may be coarse-grained producing a soil that is almost gravelly, though it is usually finer grained and often shaly. There is in all parts of it enough sand to make a soil that is quite sandy.

It occurs chiefly in Iron, St. Francois, Ste. Genevieve and Madison counties. In St. Francois county it occupies a large area lying mainly northeast of Farmington. The eastern part of this area lies in Ste. Genevieve county. The Iron county areas are rather small and lie in the eastern part of the county. The Madison county area is larger and extends northwestward from Fredericktown, into St. Francois county as a belt several miles in width. Elsewhere this sandstone occurs in such small areas that they cannot be well shown on the map.

Around that border of these areas where the sandstone goes beneath the adjacent limestone the soil of the sandstone area is considerably modified by the remnants of the limestone soil still mixed with it. The St. Francois-Ste. Genevieve county area is surrounded on all sides with the limestone. Elsewhere the limestone occurs only on one side while granite and porphyry lies on the other.

Timber.

The timber growth on this soil is, practically everywhere on the uplands, a scrub oak. In a few places where the amount of clay in the soil is unusually great, White and Red Oak are found. The scrub oak consists of scrubby growth of Post Oak chiefly with Black Oak and Black Jack less abundant. The usual bottom land timber of the region grows on the alluvial lands of this area.

The Soils.

This area has not been differentiated into types. The soils vary from place to place in the percentages of sand and clay in them but not enough is known about the area to differentiate the soil into types. The alluvial soils are of course distinct from the upland soils but there are no large streams anywhere within the areas of this group so they occur in such small quantity that they may safely be neglected.

The upland soils are everywhere sandy but in few if any places are they too sandy for good agricultural soils. The percentage of clay is usually large enough to render them sufficiently retentive of moisture and to prevent undue leaching.

It is a stone-free soil and where the topography is rolling is somewhat subject to washing. It does not wash so badly as the Hillsboro soils, however, on account of its occurrence in a smoother area of country.

It does not produce heavy crops, partly on account of its natural barrenness but chiefly on account of the treatment given it.

Like all the soils of the Ozark region, it has good pysical character. Its mineral plant food is low except potash which is moderately high. Its lime and phosphorus are low. The main deficiencies, however,

are its low humus and nitrogen content. Both these absolute necessities have been largely used up and are not being put back.

The neighborhood of the mining industry of St. Francois county has caused it to be neglected to a still greater extent during the last ten years than formerly. There are some abandoned farms on it.

This soil is not so good as either of the soils in the preceding groups. Its area stands in rather sharp contrast with those areas, both in the proportion of it in cultivation and in the character of the improvements found on the farms. These features stand out clearly in a general view of the areas of both kinds of soil, such as can be obtained from high points on the hills surrounding the basins in which they occur. Not more than 50 per cent of the LaMotte area is in cultivation while fully 75 per cent of the surrounding area of Caledonia soils is cleared.

The St. Francois Soils.

This small group of soils covers an area having the least agricultural value of any of the soil groups in the state. An extremely small proportion of the area is in cultivation. This is due partly to the nature of the soil itself and partly to the topography. These soils occur in small areas scattered over several counties in the eastern part of the Ozark region. The largest areas are in Iron, Madison, St. Francois, and Washington counties. Smaller areas occur in several other counties.

The rocks are granites and porphyries. These are hard, usually compound rocks of igneous origin. They disintegrate very slowly usually, especially the porphyry. These are the lowest rocks that are exposed at the surface within the boundaries of the state. They underlie all the other rocks and so far as our knowledge goes there is no rock of a different character underlying them. They seem to extend downward indefinitely. They make up the foundation on which the rest of the state was built. It is only in a few places where these rocks have been bowed up that they are exposed at the surface by the erosion away of the rocks that belong above them.

These rocks have been encountered in deep drill holes in several parts of the state, at Carthage at a depth of nearly 2000 feet, at St. Louis at a depth of about 3000 feet, in Camden county at a depth of about 1200 feet.

The topography is rough. Only a very small area of it is smooth enough to cultivate. The greater part of it consists of steep mountain sides Almost all of the small areas shown on the map is a hill from 200 to 700 feet higher than the surrounding country with rounded peak-like top and steep slopes. The larger areas consist of groups of such hills with narrow deep valleys between. The

valleys are mere gorges, usually too narrow for even small fields. The bare rock is exposed frequently on these steep hill sides, though there is enough soil to permit the growth of a cover of trees.

The only level tracts are two or three rather small areas underlain by granite. One area lies northeast of Ironton. It extends northeastward to the vicinity of Knoblick.

The timber consists of Black Oak, Red Oak, White Oak, Post Oak, and Pine. Black and Red Oak are the most abundant trees. Post Oak grows on the few areas of flats. Most of the timber now growing on these areas, especially in St. Francois, Madison and Washington counties, is second growth. The original virgin forest was cut for charcoal during the time when iron smelting was an important industry in southeastern Missouri.

There are two general soil types, neither of which, however, is of any importance in agriculture.

One is the stony hillside soil of the porphyry areas. The fine material is a gray silt and clay with a yellowish gray subsoil. It is usually full of angular fragments of the rock, varying in size from small sand-like grains up to tons in weight. They would seriously interfere with cultivation even if the land was smooth enough. Of the total area of this kind of country in the region, amounting to several hundred square miles, probably not one square mile is in cultivation.

The other soil is the gray silty clay overlying the more level granite areas. This is a silt or silty clay gray in color with a yellowish subsoil. The amount of stone fragments in it is, as a rule, not great. In places it is nearly free of stone. It is a rather intractable soil not easily cultivated and yielding very little crop.

Probably one-fifth of the area of this soil has been cleared and cultivated but it cannot be called an agricultural soil.

The area including the St. Francois, LaMotte and Fredericktown soils is, from the point of view of scenery, one of the most interesting in the state. This lies in the great contrasts between the level or gently undulating areas of limestone soils in the limestone basins, well cultivated and dotted with prosperous looking homesteads, and the steep, high, timber covered mountain sides surrounding them. The smooth areas run up to the foot of the mountains and the change is a sudden one.

Another feature lending interest to the country is the contrast, along the same streams, between the low grass-covered banks and the broad valley in the limestone basins along which the streams flow in a leisurely way, and the steep-sided, deep, narrow valleys or the "shut ins" where the streams plunge noisily over the stones in their narrow channels.

PART II.

AGRICULTURAL CONDITIONS IN THE OZARK REGION.

THE REGION IN GENERAL.

The Ozark region of Missouri is unique. It is the only region of its kind in the world. Its combination of special characteristics differentiate it not only from its surrounding country, but from all other known regions of the world. Its special characteristics are the product of the four factors of character of rock, geological structure or attitude of rock, erosion and climate. The first of these factors is the fundamental factor. It is the one that is unique. It is the one that most completely differentiates the region from all others. The attitude of the rocks is not essentially different from that of many other regions. Erosion has acted in the same way here as it would have acted in any other region having the same kind of rock, while the climate does not differ from that of the country immediately east and west of it.

It is a region that, in comparison with the country north, east and west of it, has been somewhat unattractive as an agricultural region. It has lagged behind therefore in agricultural development. This has been due to the nature of the soil, the topography and the vegetation.

As shown in the first part of this report it is a region of stony soils, of rather hilly topography and of timber covered or brush covered land. In addition to these characteristics the soil, while not infertile, is less fertile than the black prairie soils of adjacent regions.

These characteristics served to retard its development as long as there was an abundance of fertile prairie land that could be had for the asking. It could not appeal strongly to the practical business like, far-seeing pioneer from the northern and northeastern states who came west in search of rich land that could be cultivated easily and quickly. It did not appeal to the man who desired to farm on a large scale and in the old way. It did not appeal to a grain growing farmer who desired to operate on a large scale. The timber and brush cover made its subjection to the plow slow and costly in time and money. It could appeal strongly only to a people who had adapted themselves to a timber covered, hilly country of moderate fertility.

The Early Immigrants.

The people of the southern Appalachian region found in this region a nearer approach to the one to which they had adjusted themselves than any other group of migrating people in the country. The first settlers in the region were from this latter part of the United States. They were the only occupants of the region up to the latter part of the nineteenth century when railway building in the region brought in people from the north and from Europe. These latter, however, settled only along the railway lines. They did not spread out over the country as a whole. Even up to the present time the greater part of the region is occupied almost extensively by the descendants of these early settlers. The iron mining in the Central part of the region and the lead and zinc mining in the southwestern part attracted laborers from the outside but they rarely became part of the agricultural population. As long as the mining continued in any particular camp they continued with it and when it declined they left it. They did not take up land and become permanent settlers.

In the lead mining regions of the eastern and northeastern Ozarks, however, the mining was carried on, until recently, chiefly by the farmers. They mined in the winter months and farmed during the summer. They constituted part of the permanent population. In the eastern Ozarks, however, a considerable portion of them were of French origin, descendants from the early French settlers along the Mississippi river. They never extended west of the mining region and the number who became permanent Ozark settlers was small.

The best land of the region lies in long narrow strips along the creeks and rivers. Between these lie broader belts of rough, stony, timbered land varying from one to several miles in width. The people were, and in portions of the region are still, situated only along these valleys. Each valley is isolated, more or less, from the others. The people in each gradually develop characteristics peculiar to it or a certain style of dwellings, barns, crops or methods of cultivation. Whole valleys have become the property of one family; the original settler and his immediate family selecting only the richest of the alluvial lands. The second and third generations have extended the clearing to the more gentle and less stony of the adjacent slopes or even into the "flat woods" or "Barrens," the flattish undissected strip of upland along the axis of the belt between adjacent creeks. The development of the region as a whole, except a few localities near modern railroad towns where the presence of the real estate agent has caused a temporary boom, has been brought about in this way. It is the result of the natural growth of the native population. The influx from the outside has been small, except where the region has

been occupied by Germans. In such cases the original population was bought out and the German population took the place of the original. The Germans were not *added to* the original population and there has been slight influx of Germans since the first colonization. The increase in German population has been the natural increase of the original population of the colonies.

History of Settlement.

The first settlement of the regon took place before the beginning of railway development in the United States. The first settlers were French colonists who came up the river from New Orleans. The permanent settlers remained near the river, while the miners and adventurers sought the lead region of what is now Madison, St. Francois, and Washington counties. French colonists settled at Ste. Genevieve in the first years of the eighteenth century, at New Madrid a few years later and St. Louis in 1765. The fact that the French settlers came in colonies and settled in villages together with the fact that the peculiar long, narrow subdivisions of land characteristic of the subdivisions of European village communities is found only at New Madrid and Ste. Genevieve indicates that the French did not do a great deal toward the permanent agricultural development of the Ozarks. All the chert-free limestone basins in the Eastern Ozarks are covered with French and Spanish grants but none of them have the characteristic long, narrow subdivisions. They are usually large tracts that were granted chiefly for mining purposes or else were unable to attract colonists. There are, however, many small grants that were made to permanent settlers but most of them seem to have been made shortly before the American regime commenced and after the influx of American settlers. Many of the names of the grantees are American names. This is not true, however, of many of the older and larger grants.

Practically no settlement took place in the region except that along the Mississippi and in the limestone basins of the Eastern Ozarks until near the end of the first quarter of the nineteenth century. In 1819 when Schoolcraft traveled across what is now Washington, Crawford, Dent, Texas, Wright, Douglas, Taney, and Ozark counties he found only one or two squatters, engaged in hunting chiefly, after he left the settlements at Potosi in Washington county. Probably occasional squatters had located themselves at various points in the valleys of the northern border but the great central and southwestern parts of the region were the winter hunting grounds of the Osage Indians. There were no roadways across the region at that time.

The Early Roadways.

Probably no road extended further west of the Mississippi than Potosi earlier than 1820.

From Potosi southwestward, ran an ancient Indian thoroughfare—a mere footpath or bridle path. It was known by the white settlers as the Osage trace or the White river trace. It ran from Potosi southwestward, following approximately the line of the existing road from that place to Webster but passing about a mile north of where that town now stands. It ran thence southwestward to Huzza creek not far from where the village of Davisville is now situated. It turned thence southward for several miles and then again southwestward. It passed about five miles north of where Salem now stands, then across the head waters of Dry Fork of Meramec to the vicinity of Licking. Thence it crossed Big Piney at Plattner's Dam, passed a little way to the south of Success and crossed Roubidaux Creek either at Turley or Flat Rock. It crossed the Gasconade river at Hartville and ran thence to where Springfield now stands, probably running near the present site of Marshfield. From Springfield it followed the track that was later called the "wire" road, running from Springfield to Forth Smith on the Arkansas river. This latter end was not a part of the Osage or White river trace.

This became the great settlers thoroughfare for the region, at least for the southern and the southwestern parts. They came in two streams, both originating from the same region—the hilly region of the Southern Appalachians. One came across Tennessee and Kentucky to "The Iron Banks" ferry, where Columbus, Kentucky, stands at present. Their route lay thence northwestward across the lowlands through Charleston and Benton to Jackson. Then it followed the old Jackson and Farmington road to the latter town where it met the other stream which had come across Kentucky and Southern Illinois to Ste. Genevieve or Herculanaeum. The united stream flowed thence southwestward along the White river trace through Caledonia, Courtois Diggings, The Lick Settlement (Licking) and Hartville to Springfield. Here the White River trace joined the St. Louis and Fort Gibson road running southwest of Springfield across what is now Greene, Christian, Stone, and Barry counties into Arkansas. Before 1840, however, many roads had been located in all directions across the region.

The Early Settlers.

The settlers who came to this region were not the poor whites of the slave-holding regions of the south—the lower coastal plain and the Piedmont. They were the more independent hill people from the more mountainous sections where they had had rather remote

relations with the slave-holding class. Occasionally an especially prosperous man among these owned a few slaves which he brought with him but they were few. They came from a hilly region where tillable land consisted chiefly of the alluvial strips along the streams, where the streams were clear, springs abundant and timber plentiful. They sought similar conditions in their new home. These they easily found. There was one rather important difference, however, between the country they left and the one to which they came. The one they left was heavily timbered, both hills and valleys. The greater part of the one to which they came had heavy timber in the valleys and on the very stony soils while on the smooth upland between the streams there were large areas of park-like, open grass land. The few trees were large as a rule. Brush patches or areas of small timber rarely occurred. In the Ozark Center region flat upland watersheds were rare in their occurrence so this area was a forested region. The virgin timber standing on it at the present time shows that it has been timber covered for at least two to three hundred years. On the Ozark Plateau, however, there are large areas of smooth upland. These were treeless prairies or grassy oak openings until the middle of the nineteenth century. The same statement can be made concerning all the western Ozark Border.

The Early Agriculture.

The prairies and oak openings furnished abundant summer pasture for large herds of cattle, and where the dry grass was not burned early in the winter it fell over making a natural blanket over the whole country beneath which the grass remained green until late in the winter. Old settlers assert that young stock would go through the winter without other feed than what they got from the range. Much of the winter pasture, doubtless lay in the more protected bottom lands. The timber on the bottom lands and elsewhere was sufficient to furnish abundant mast not only to keep hogs alive but to prepare them for market. The virgin lands of the creek and river bottoms produced good crops of corn also with a comparatively small amount of labor. The conditions were extremely favorable, therefore, for stock raising. There was abundant and cheap food and abundant water along all the rivers and large creeks and at the many springs which occurred in almost every hollow.

Grain farming for the market was impossible on account of the lack of facilities for transportation. There were no railways. The wagon roads were rough and hilly. The streams were, except in rare cases, not navigable. Lumbering also was not possible because of the same lack of facilities for transportation and also the lack of

a market for such lumber as the region would produce. The mining industry until the middle of the century was confined to a few counties in the eastern part of the region. It has never been of any importance in the south-central part of the state and has fluctuated even in the mining regions greatly within short periods of time. The only two parts of the region where it has been in any way permanent are the eastern and the southwestern. The natural conditions surrounding the original settlers, therefore, made stock raising the only industry that was practicable. Stock could easily be driven to the Missouri, Mississippi, Lower White and Black river shipping points.

The Second Agricultural Stage.

So long as cultivation was confined to the alluvial strips along the creeks the products of the soil were sufficient to satisfy all demands of the people. The bottom lands furnished an abundant supply of grain for all purposes while the uplands furnished abundant free range for everyone's live stock. The original immigrants did not occupy all the alluvial land. There was in most cases a supply for the first generation of descendants. By the time the third generation were ready to become farmers, however, the bottom lands were all in cultivation. They had to make farms from the less desirable lands of the uplands or the hills. At first they selected the level lands of the axial belt of the dividing ridges. These were smooth and, in most parts of the region, free or nearly free from stone. The soil is not fertile—not so productive as the stony lands of the hilly belts adjacent to the valleys—but they were much easier to cultivate and were usually free or nearly free of timber. They were easily put into cultivation.

This invasion of the upland effected a profound change in the economic life of the people. It did not take place suddenly but came on gradually, almost imperceptibly. In many parts of the region, particularly the central part, the readjustment in response to it has not yet taken place. The fencing of part of the upland reduced the free open common pasture land and therefore the food supply for live stock to that extent. Another change took place, however, that had a much greater effect in decreasing the available grazing land than the fencing of part of it. Even at the present time there is still a large amount of land not under fence.

The Consequences.

As a result of the building of rail fences on the ridges and partly also those in the valleys the annual prairie and woods fires were gradually stopped. The fencing material was inflammable and had to be protected. Fires were stopped, therefore, wherever possible or at least

much restricted in their original freedom. The stopping of the woods fires allowed the brush to spring up and grow. As long as there was an annual fire which raged through grass from three to eight feet high and thick on the ground, all forest-tree plants were killed down to the ground every year. During the ages preceding man's appearance in the region acorns had been scattered well over the region. Young plants sprang up from them every spring but were killed down in the fall. The roots were not killed, however, but remained to send up young shoots every spring. They in turn were killed in the succeeding autumn. This continued for ages. The roots remained alive and spread through the ground, making underground rootstock networks often nearly filling the ground down to a depth of a few inches. When the annual fires were stopped these roots sent up hundreds of shoots which grew rapidly and in the space of a few years produced a mass of scrubby brush that smothered out the grass completely. At first the brush was so thick it could not grow to any size. For many years it stood at about the height of a man's shoulder and from that height down. Gradually the more vigorous individuals got a little ahead and the weak ones died out. At the present time there are small areas scattered abundantly over the nearly level high silt or clay ridges of the Ozarks covered with a thick growth of young Post Oak or Black Jack trees from 2 to six inches in diameter that have grown from such brush patches. All these ridges are now covered with such a growth where they are not in cultivation. The result is that the grass has been completely killed out. In many parts of the region there is abundant vacant land to furnish range for more stock than the country now has but it is covered with young trees rather than grass.

In the hilly, stony belts of country between the smooth clay ridges or the original slightly stony ridges and prairies, the same process has gone on at least so far as the result is concerned. The growth of timber has completely killed out the grass in some places and greatly injured it everywhere. It has not been affected by the growth of post oaks, however. The hill lands are not the natural habitat of these trees. They occur only sparingly. The trees that grow on the stony lands are Black, Red and White Oaks. None of them will form underground stools like those formed by the Black Jacks and Post Oaks of the flat clay ridges. There were enough large trees, however, to keep the ground well seeded. As soon as the fires were stopped young trees started up from these seed, making a cover much less dense than the post oak and black jack "runners" of the smooth uplands but dense enough to smother out the grass.

At the present time there are relatively few areas of any size where the original Blue Stem grass, which grew everywhere over the region originally, grows with even half its original luxuriance. There is one area lying in Morgan and Camden counties, another in the Pine region of the southeastern Ozarks, and a third in parts of Ozark and Taney counties. In the rest of the region small patches occur but the great areas of woodland produce as a rule nothing but weeds or chiefly weeds with a small amount of grass. The range, however, in much of this stony, hilly belt even where most of the grass has been killed, is still much better than are the timber belts of the flatter ridges. The grass is somewhat more abundant, but in many places the ground is covered by a dense growth of annuals, many of which belong to the Leguminoseae. In the autumn large areas of wild pea vines and "Beggar Lice" furnish excellent grazing for cattle.

It is possible that the growth of trees and brush has not been the sole cause of the killing out of the grass. It may have been caused partly by overgrazing and tramping. The effect of the latter, if it was effective at all, was probably confined to the clay lands of the ridges. The stony lands could not be injured by the tramping of cattle and horses. The fact that the range continued to be good until the brush covered the country is good evidence that the shade and moisture consumption by the trees were the principal factors.

The Abandonment of Stock Raising.

The destruction of the natural pastures has caused the abandonment or serious curtailment of the stock raising industry. The making of artificial pastures of tame grasses on the cleared lands has not kept pace with the destruction of the natural ones. That is evident, since the destruction of the original as pointed out above is the result, not of the taking up of the land and putting it into cultivation but of the growth of brush. The making of the tame grass pastures is a development of the future. The old Blue Stem was naturally adapted to the soil and climate. It had become so through long ages during which the law of the survival of the toughest, the strongest, the best, was the only law that prevailed. Man has not yet found or at least has not universally adopted a substitute for it.

The Adoption of Grain Farming.

The change described above has come for the whole region. It came in some parts of it earlier than in others, depending chiefly upon the rapidity with which the upland was occupied and the native grasses killed out. It cannot be described, however, as a change peculiar to the Ozark region. It is one that has taken place over

a large part of the United States. The earliest settlers were primitive stockmen, growing their stock on the native grasses of the unoccupied land. The change did not come in the Ozark region until long after it had taken place in the greater part of the area surrounding it because of the slower rate at which the former was settled up. The usual farming system, following the primitive stock raising, is a system of grain growing. This takes place in practically all cases where the soil is fertile, the land smooth or relatively so and where means of transportation exist. The Ozark farmer followed the same order of economic development. He became a grain grower and ceased to be a stockman or at least decreased greatly his operations as a stockman. This change took place in the Ozark Plateau and Ozark Center within the last 15 or twenty years. It took place in the Ozark Border from 20 to 35 years ago or even earlier than that in a few cases.

The Results in the Ozark Center and Ozark Plateau.

In the Ozark Center and Ozark Plateau, taking these areas as a whole, the income from exclusive or nearly exclusive grain growing has been small. Grain farming has not been profitable. The upland soils do not produce profitable crops of grain for many years in succession by the ordinary method of cultivation. The bottom land is too limited in amount to produce sufficient grain to raise the income of the country as a whole up to what it was when the total land area was producing something. The change has not been a satisfactory one. It came with the force of a demand and without invitation, though as a result of the action of the people of the country. The decreased income of the individual has resulted in unrest and dissatisfaction. The people realize that the country cannot be prosperous as a grain growing region but they do not yet, in the region as a whole, see what to do next. They realize that a new adjustment must come but have not universally agreed on the particular kind of adjustment that is necessary. Sporadic attempts have been made to find the proper remedy. Many men have left the country to find free range and all its attendant attractions to the born and bred pioneer in the far west. Others, more willing to change their mode of life, have been attracted by the alluring literature of the fruit-tree nurseryman and the railway advertisements. Still others and much the larger number have merely curtailed their operations—are growing fewer cattle and hogs and therefore making less profit. The improvement of the quality of the cattle, sheep and horses has not been sufficient to compensate for this curtailment. Hogs, however, have been improved so that as good a grade of hogs may be found in the Ozarks as in most parts of the state. The average farmer at the present time has a smaller net income than he or his progenitor had fifty years ago. This is true of the

bottom land farmers as well as the ridge farmers. The farms that were orignally large have been subdivided until they would yield to each head of a family a smaller total income even if he had access to free range as he formerly did. This also has been destroyed so that his income has been still further diminished.

Social conditions in parts of the region have not improved and and in some ways they are not so pleasant to the existing population as they were under the old regime. One of the factors, and an important one, producing this result is the constant drain made on the most vigorous and effective part of the populations of the country. The young men and women and many of the more progressive and socially desirable middle aged men and women leave the region for the cities or for the attractively and skilfully advertised lands of the west.

Another factor is the change which has taken place in the facilities for communication. Formerly the roadways were the sole transportation lines. All products consumed by the population except those grown or produced at home were transported long distances by wagon. All products taken out of the country went by the same routes. They were kept well beaten out, therefore. They were laid out with the demand of this traffic in mind. There was practically no other factor controlling their location. This caused their location along lines of easiest passage—along the valleys. Usually they ran along one side of the valley, being confined to this by the farms. They wound picturesquely along these valleys through the walnut groves by the farm houses, never in straight lines and also rarely over the hills, except when necessary to pass from one valley to another.

The present traffic is less than formerly. The roads are, therefore raw, gullied, stony, untamed and usually unworked. They have been shifted from their former courses which were determined by the route offering the least resistance to one that follows the land lines irrespective of the shape of the country. They run, therefore, in straight lines across deep hollows, up steep hills, wholly disregarding the nature of the country. There has been very little attempt to grade them and no attempt at proper drainage. On the slopes therefore, the road is soon worn into a hollow, down which the drainage water flows during heavy rains. The finer materials of the road are soon washed out, leaving the surface covered with a layer of loose stones of varying sizes up to several inches in diameter. In addition to this it is often badly gullied. The stones and gullies make the hauling of a load over it impossible and any kind of passage over it difficult.

Since the advent of the railway in the region the roadways are not used so much for hauling heavy loads but their disuse and lack of care results in a serious drawback to the social life of the people.

The conditions of life within the region at the present time vary greatly with the character of the country. In no other part of the state is the contrast between the income of the owner of poor land and that of the owner of good land so great. The difference between the productive power of the best land and the poorest land is far greater, where both receive the same treatment, than in any other portion of the state. The proportion of highly productive land is smaller also than in any other part of the state.

The region as a whole is a region of farm owners. A relatively small portion of the men whose principle means of livelihood is farming are entirely landless. There is a considerable percentage of rented land but the greater part of it, except a few tracts owned by mining companies, is rented by the owners of small farms who desire to extend their operations. Renting is chiefly a neighborly affair.

The Period of Readjustment.

The conditions in the Ozark border region are somewhat different, especially on the Perryville, Union, Owensville, Osage, Springfield and Bolivar soils. In the greater part of the areas of these soils the country is smoother, the soils less stony and as a whole more productive than the soils of the Plateau and Center areas. These areas also being adjacent to the Mississippi and Missouri river valleys on the east and north and to the smooth prairies on the west developed much more rapidly than did the more interior areas. Transportation to market was easier from the border region than from the interior both because of the shorter distance and because of smoother country. The people passed through the change from primitive stock raising on wild grass pasture to a later and different agriculture many years ago. There are very few areas within these soil belts where live stock have unrestricted range of the country or have had it for the past 15 to 25 years. On account of the smoother topography, better soils and better transportation the adjustment was easier here than in the interior parts of the region. Grain growing was profitable on both the upland and bottom soils so that when live stock could not be grown on the range the natural adjustment was to grain farming with curtailed live stock. Wheat became an important money crop—for many years the main money crop. This was supplemented by hog raising but relatively little attention was paid to cattle, horses or sheep.

Later the fruit industry began to develop in certain localities and in places, chiefly in the southwest corner and in Howell and Oregon counties, has become an important industry. Apples are grown to a considerable extent but strawberry growing has become more important, especially along the railway from Greene county southwestward. For several years most of the railway stations from Springfield

to Carthage and from Monett to the Arkansas State line have been important shippers of berries. The industry is sufficiently important to cause the development of many local fruit-growing associations. Other small fruits, such as blackberries and raspberries are grown to some extent but they are not so important as strawberries. Peach growing has never been an important industry, chiefly on account of the climate. The trees do well. The crop of apples also is rendered very uncertain by late spring frosts. Strawberries are injured sometimes also.

Another phase of this fruit-growing industry is the growing of tomatoes for the local canneries. This industry is well developed in the Springfield region in the neighborhood of the railway. It has extended also into the Ozark Plateau region but has not become so well established there as it is in the southwestern border region.

In the northwestern, northern and eastern parts of the Ozark border the fruit growing industry has never been developed to any extent. It has remained a grain growing region since it abandoned its primitive stock raising system of farming.

A third readjustment to new conditions is beginning to take place in the southwestern Ozarks. This is the development of dairying. During the last five years dairying has attracted a great amount of attention in all the southwestern counties of the Ozark border. This has come as the natural development, following the intensive fruit farming, that has been going on for many years. It is very materially accelerated by the gradual waking up to the fact that no soil responds to manure better than the soils of the Ozark region and that the most effective machine for the manufacture of manure is the dairy cow when properly handled. The high price of dairy products for the last few years has been another important factor.

This interest in dairying has extended into the Ozark Plateau region, along railways. That part of the Plateau that lies near the railway has also had some development of the fruit industry but it omitted the grain growing stage on account of its soil. It is well adapted to dairying, however, and will develop it rapidly.

For a year or two there was an attempt to utilize the Springfield gravelly Black Oak soil in a few localities in Southwestern Missouri as a truck soil. A great deal of interest was aroused in potato growing. It was not maintained more than three years, however. The reason for the failure is not known. The potatoes were shipped to Texas. It was reported that they did not keep well in the Texas climate. Whether this was the real difficulty or not has never been determined. It was well demonstrated that potatoes would yield profitable crops on these soils. This occurred in the early nineties.

AGRICULTURAL POSSIBILITIES OF THE REGION.

General Conditions.

The agricultural conditions of a region are the product of many factors such as soil, topography, climate, as well as the character of the population, the condition of communication and nearness to market. The fundamental factor is the soil. When soil, topography, and climate are favorable other conditions may be modified. When these are unfavorable the county cannot become a prosperous agricultural region.

The climatic conditions are practically uniform over the whole Ozark region. The natural factors, therefore, which cause variations of conditions, within the region, are soil and topography. These often vary together and where they do not do so the controlling factor, within certain broad limits, is soil. In general terms, therefore, it is true that the agricultural conditions of the Ozark region vary with the character of the soil. Some of the conditions determined by the character of the soil and other natural factors just named are favorable to agriculture while other conditions are unfavorable. Since this report concerns the soil chiefly the favorable and unfavorable conditions determined by the soil will constitute the greater part of what is said in the following pages, though some reference will be made to other factors.

Advantages of the Region.

Adaptability of the Soil.

While the soil, taking the region as a whole, is not a highly productive one, yet there is not another area in the state of anything like equal the size of the Ozark region that has a soil that is moderately well adapted to as many different phases of agricultural production. The fine part of the soil is very fine, making it readily adaptable to grasses and to a majority of the small cereals. It is true that tame grass pastures are not abundant in the region but that is due to the absence of any demand for them until recently and also to the low content of the humus supply. So far as the physical character of the soil is concerned it is adapted to most of the grasses, especially to the bunch grasses. All except the most extremely stony land will grow blue grass also where the humus supply is made adequate. The percentage of clay and silt in the soil is abundantly sufficient to constitute what the English people call a natural grass soil.

All of the stony and gravelly soils and the alluvial soils are natural clover soils. To these might be added the stony or gravel-free soils which have a brownish or reddish color and a reddish subsoil. Even on

the flat silty uplands clover may be grown if a little care is taken in seeding it. On the other soils, except where clover and grain have been grown until the percentage of lime and humus has become low, the failure to get a stand of clover is the exception rather than the rule. There is every reason to think the gravelly and stony upland soils will grow alfalfa when the farmers have made up their minds to give the matter a thorough test.

The Ozark border region is second in importance in wheat raising only to the Missouri river bottom lands and the Loess soils adjacent to the river. The quality of the wheat is equal to any winter wheat grown in the Central West. The production per acre is not high but under proper rotation it could be materially increased.

The gravel and stones in the soil insure its perfect drainage while the fineness of the soil enables it to retain abundant moisture in seasons of average rainfall. Where the soil is well cultivated and kept supplied with humus it stands dry weather as well as the average soil of the other parts of the state. This insures its adaptability to corn growing when its fertility is mantained at a sufficient level. The yield of corn on the upland soils after they have been run in corn through the period of stump eradication is low. It will not average more than 20 or 25 bushels per acre. But where clover is grown and manure used on the land it will produce 35 bushels per acre, and, in good seasons, 40 to 45. Corn should not be grown on this land oftener than two years in five on account of its low fertility, not on account of its physical character. The bottom lands produce from 40 to 75 bushels per acre under average good conditions.

Its gravelly and stony nature insure its adaptability to a long list of vegetables. Vegetable gardens are, where they receive proper care and cultivation, almost always good and the range of products great. Potatoes, of both kinds, and beans do especially well.

The proportion of the total area of the country that, under a safe system of permanent agriculture, could be cropped in corn any one year is very small on account of the relatively small proportion of the area that is cultivated and the small proportion of that that should be cropped in corn in any year.

Water Supply.

The nature of the soil and of the underlying rocks causes the water supply of the region to be extraordinarily pure but over large areas it is not easily available. In the valleys of the large streams it is abundant. The perennial streams of the region are all large. There is no such thing as a brook in the whole region. The many springs that are found in the more hilly portions of the region supply a small

stream that may run over the surface for a few thousand feet but it soon sinks beneath the gravel of its channel. On the uplands permanent "living" water must be sought in wells usually more than 100 feet deep. Good water can be reached in such wells practically everywhere in the region, but it is, in practically all cases, found in the rock, or on the contact between the rock and the loose clay and stones above it. A driven well is an impossibility in the whole region. Occasionally a small supply of water may be found in a shallow well dug at the head of a small hollow. Hundreds of the upland wells, however, that do not penetrate well into the solid rock remain dry or are dry in dry weather. Where wells are not dug or bored, water must be stored in reservoirs, either cisterns or open reservoirs. Such a supply is not satisfactory, though it is a common one. It is only on the creek bottoms or in the heads of hollows or sags in the upland that a good supply of water can usually be found above the solid bed rock.

Timber.

A considerable percentage of the area of the Ozark region will always be covered with timber. A relatively small part of it, however, will grow timber of very great commercial value. A great deal of the original growth of native timber has been used for commercial purposes but only for the cheaper grades of timber and the amount realized from it has been little more than the cost of cutting, preparing, and marketing it. It has not been an asset of very great value to the state. The pine region of the Ozark center counties makes the only exception to this general statement. It is of considerable value, however, to the farmers of the region. It furnishes an abundant supply of fuel and cheap building material; fence posts, framing timber, shingles, and ordinary oak lumber are cheap and abundant. The fencing and barn problems are easily solved and the fuel supply never fails. While these cannot be considered as important sources of income they are important in their reduction of the cost of farm equipment and of living.

Climate.

The climate of the region combined with the warm well drained soil is in many respects a decided advantage when compared with the surrounding country. Rainfall varies from about 38 inches on the Missouri river to 46 inches on the south line of the state, the maximum reaching about 50 inches in the southeastern part of the region where it abuts against the lowland region. The temperature varies from an annual average of 52 degrees along the Missouri to about 55 degrees in the southeastern corner of the area. These averages do not differ in any important respect from those in the same latitude east of this

region. The character of the soil, however, is such as to make the winters dry and while the air is cold yet the absence of mud allows a freedom and ease of communication that is not found in other localities with a similar air temperature and rainfall. The advent of spring is earlier than in the neighboring regions not because of a more rapid increase of air temperature than in neighboring regions but chiefly because of the more ready response of the dry soil to the more direct rays of the sun. The pasture season begins earlier than in the clay soils of the east and persists until later in the autumn.

Structural Material.

The abundance of cheap timber for posts, framing, boxing, and firewood does not complete the list of cheap structural material found abundantly in the region. Limestone of excellent quality is found in many places and of fair quality for structural work about the farm practically everywhere. Limestone suitable for the manufacture of good building lime is especially abundant in the area of Springfield soils and in practically all other portions of the region a dark lime can be made. In modern farm construction cement is assuming a constantly increasing importance. The use of cement requires the use of gravel or broken stone. Gravel occurs in great abundance in practically every creek or river channel in the region and in many localities flint stones occur in great abundance already broken to sizes needed in concrete work. They retain an angularity as great as that of ordinary machine-broken stone. This is an excellent road material also and the supply is inexhaustible.

Disadvantages of the Region.

Topography.

Taking the region as a whole the topography constitutes a rather important hindrance to tillage. There is a relatively small area of very smooth land, though there are considerable areas which are not rough enough to hinder good cultivation. Like all the states lying south of the Illinoisan, Iowan, and Wisconsin, glacial boundaries Missouri has no very large areas of flat land. It is nearly all dissected more or less by streams. The Ozark region, being highest and having harder rocks, is cut the deepest and its roughness has not been reduced by the wearing down of the upland while the valleys were being cut out. Its angularity has not been softened by extensive weathering of its rocky bluffs. The hilly land of the Ozark region can be much more safely cultivated however than can land in North Missouri of equal roughness. The latter has a clay or silt soil without a sand or gravel con-

stituent. It cannot absorb water rapidly. The rainfall, when heavy, runs off and takes with it a great deal of soil. The stony and gravelly soil of the Ozark region, on the other hand, absorbs a great deal of the rainfall. A very small portion of it runs off over the surface, even on rather steep slopes, except the relatively small areas where the soil is free from stone and gravel. While the more hilly part of the Ozark region is more deeply cut up by valleys than the more hilly portions of northern Missouri yet in the former the intricacy of the cutting is much less than in the latter. In North Missouri a forty acre tract may have and often does have as many as ten small ravines while in the Ozark region there is rarely more than three or four on an area of equal size.

Growth of Brush.

Practically the whole region was adapted to timber growth and considerable areas of it were actually covered with timber when settlement began. Where prairies existed they were not destitute of trees over large areas but were open grass lands with enough trees scattered over it to seed the land. The ground, even where trees did not exist, was full of roots. As soon as these got an opportunity to grow, growth commenced. By far the greater part of the area became covered with brush before it was broken by the plow. If it was not timber land it was at least brush land.

The universal method of preparing the land for the plow in the region is to cut the trees and brush, and leave the stumps and roots in place. The roots are never pulled out before the land is plowed. This is practically universal in the clearing up of the region. The trees and brush are chiefly oak—deep rooted trees and very tenacious of life. The roots remain alive in the soil for years and every year send up a vigorous crop of young sprouts. This continues for 5 to 8 years, or about as long as the ordinary stony upland soils produce fair crops of grain. It is not profitable to grow clover for hay on such land because of the impossibility of running a mower among the many stumps. Putting the land in pasture allows the brush to take possession of it in a surprisingly short time. The expense of keeping the brush down when the land is in pasture is heavy in proportion to the cost of the land and of the original clearing. It is protracted for many years, the stumps not dying so rapidly as when they are being bruised and broken during the cultivating season by the plow. Goats have been tried in a few places with apparent success. That, however, is expensive since first cost of the stock is considerable, also, and the possibility of selling the flock when their work is done rather doubtful. The average small farmer of the Ozark region has not yet seen his way clear

to the adoption of this method of dealing with the matter. He cultivates the land in corn continuously for several years, cutting the sprouts once or twice each year until the stumps are dead. Occasional hickory or white oak roots remain alive and sprout after the land has been in cultivation for 20 years.

By the time the stumps are rotted out of the ground the land is pretty well exhausted of its humus. This is especially true if it be gravelly or stony hill land, though it applies to the bottom land also only to a slightly less degree. As soon as this condition is reached on the gravelly soils a crop of sassafras and persimmon sprouts are practically sure to spring up. Where continuous warfare is not waged against the sassafras especially, it will grow up in a very few years thick enough to exclude practically all other growth. These are difficult to eradicate as long as the land is in corn. A rotation with clover, however, and a few years with a June and August mowing will kill them out completely. As long as the land is kept well supplied with humus and has a crop of hay mowed from it every few years it will not be difficult to deal with both of these growths.

Baking of the Soil.

The fine grained constituents of the soils of the Ozark region are clay and silt. The ordinary term for both is clay. Taking the region over its soil is finer in grain than that of any other area of considerable size in the state. The almost universal system of grain farming in the region, especially while the land is new and rather productive, reduces the humus content rapidly. The lower this becomes, the greater is the tendency of the soil to puddle. When such a soil dries it becomes very hard. If it be worked while it is too wet it becomes very difficult to cultivate and the effect of one working at the wrong time will persist for many years. The farmer who is unfamiliar with this characteristic of the soil is often deceived and led to work his soil when too wet because of its normally loose loamy texture. This loamy texture is due to the gravel in it rather than sand, the finer constituent of the soil being finer than sand.

This characteristic is more pronounced in the upland soils than in the bottom land soils although the former are more stony or gravelly than the latter. The alluvial soils of the bottom land lost a considerable percentage of their finest grained constituents in the process of making. They are usually better supplied with humus also. While they were still occupied with their native growth the leaves were not burned off every autumn as they were on the hills. They decomposed into a layer of humus. The soil in the small hollows and narrow valleys that have no perennial streams as well as that in the larger valleys

around the mouths of tributary hollows does not differ from the upland soils in this respect.

Fortunately the gravel constituent in these soils makes them much less intractable than they would be without them. Without the gravel to soften them up they would rebel absolutely against the treatment usually given them.

Cultivation of the Stony Land.

There is practically no type of soil in the Ozark region that is entirely free from loose stones. Some of the types are stone-free over most of their area and one or two are practically stone-free. The rule, however, is a more or less stony soil. Within the areas where stone is most abundant in the stony types, the soils occupying the two topographic extremes, the bottom lands and the flat topped ridges, are nearer free from stone than the other types. The bottom lands are apt to be stony along the outer margins, near the hill border, especially in the neighborhood of the mouths of hollows. These places, however, are usually gravelly rather than stony. The low bottom lands in the broader bottoms are stone free for several feet in depth of soil. The narrow dry hollows are often more stony than the hill lands. The flat topped ridges are never, or rarely, gravelly. They have usually stone-free silt or clay soils or else silt or clay soils with a varying proportion of "chunk rock," or flint stones, ranging up to a foot in diameter, very few of them being small. They, like the stones in all the soils, are angular, often with sharp edges. Beneath a silt layer of about a foot these upland flats are as stony as any of the region. It is only the soil layer that is stone free or partially so.

The farmer in the region must of necessity, cultivate stony or gravelly land. This stone when pure, fresh, and not disintegrated is as hard as any stone in existence. It wears tools, especially farming tools, rapidly. Horses wear their shoes rapidly and must be kept shod at all times. The larger stones in the soil make efficient plowing rather difficult. The ordinary breaking plow is apt to be thrown out of the ground very often by striking them. On some of the very stony land it is almost impossible to plow with any thing but a sharp pointed plow, that will slip off the stones when it strikes them without being thrown out of the ground.

The disadvantages arising from this condition can be overcome by picking the stones up and hauling them off the land. This is a rather expensive undertaking but not so much so as that of taking the stones from the stony glacial soils of the northern states. In the Ozark region a stone too large for a man to lift and place on a wagon practically never occurs on land that can be converted into farm land. In the

northern states stones of such a size are very common. The clearing of the average stony land of the Ozark region of its stones can be done at a cost of from $5.00 to $20.00 per acre.

SYSTEMS OF FARMING ADAPTED TO THE REGIONS.

Systems of farming that are profitable in any particular region are determined by the nature of the country, its position or relation to market and to its climate.

The Ozark region is one of very pronounced characteristics. It is unlike any other area of equal, or approximately equal size in the world. Profitable farming in such a region must be definitely adjusted to it. It is not an area where loose and diverse methods with no relation to environment can be profitable. Several systems may be practiced in the region but each one must be definite in its adjustment.

In the following pages certain systems to which the region is adapted, as well as certain others to which it is not adapted, are discussed very briefly.

Grain Farming.

Grain farming on an extensive scale is an impossibility in any part of the Ozark region. The alluvial soils are all excellent grain soils but the proportion of these to the total area is too small to permit the production of a surplus of grain. The best of the upland soils produce fair crops of grain also, but the area of this is small. There can never be a surplus of corn, at least, produced in any part of the region after the adjustment of agricultural practice to the natural environment of soil and climate. There is such a large area that is adapted to grazing alone that the grain production can never run beyond the amount that the stock that is grown on the pastures will demand. The impression seems to prevail in many places that stock in the Ozark region does not need a great deal of winter feed. The facts are, however, that the winter feeding period is nearly as long as it is in any part of the state. When clover pastures are used it comes a little earlier in the spring and lasts until a little later in the fall than in the northern part of the state. The range grasses, however, do not appear any earlier than the tame grasses of the other parts of the state.

The nature of the soil is such that it cannot stand grain growing as continuously as the other soils of the state. On account of their loose texture and open porous character their humus supply is soon exhausted by continuous cultivation. Wheat growing has for many years assumed a high importance relative to the growth of the other grains. Corn and wheat are practically the only grains grown. As the agricultural practice adjusts itself so as to realize the greatest pos-

sible profit wheat growing will probably decline because of an increased demand for corn to feed the stock that are being grown on the pastures.

Stock Feeding.

Stock feeding, especially cattle feeding and finishing, can never become an important industry on account of the small amount of corn land.

Hog feeding on a small scale and sheep feeding can be done with profit. The clover and alfalfa land will be effective aids in this branch of the industry.

Dairying.

There are several reasons why dairying is proving to be more profitable than any other branch of agriculture in the Ozarks. The first is:

Cleanliness.

Of all the area of the Central Mississippi Valley the Ozark area has greater freedom from mud. The universal presence of stones and gravel in the soil insures solid roads and good drainage under ordinary conditions. The spring thaws have nothing like the terrors and inconveniences that accompany them in the prairie region. The thorough drainage of the soil prevents the accumulation of surplus water during the winter and the consequent heaving of the soil. The latter is practically unknown except on the flat upland clay soils.

The absence of suspended matter from the water supply is another factor in the cleanliness of the region. The running water is universally clear except during the short flood periods of the streams and the banks and channels of the streams are lined with gravel. There are no unsightly mud-lined streams on which stock must depend for water. The artificial ponds on the uplands cannot be so favorably described but their existence is not necessary. Pure water may be obtained anywhere in the region in wells of no great depth.

Climate.

The mildness of the winters, including the great amount of sunshine, promotes the comfort and health of the stock and of the farmer as well. It lessens the cost of barns and to a certain extent of feed. The number of days during the winter when cows must be kept under shelter is relatively small. Shelters must be provided, however, but most of the farms, if they be rather large ones, grow part or all of their own building material.

Roads.

The abundance of road material make it possible to build good roads all over the Ozark region at less than half the cost of the same roads elsewhere in the state. In fact over large areas the best of roads can be made by merely providing for drainage. It is usually unnecessary to provide drainage to prevent mud but it is necessary to prevent washing on the hill sides. The roads are good throughout the year, or can be made so. There is no period during the year when the farmer will be unable to get over the roads with his dairy products.

Legumes.

The ease with which leguminous crops are grown, the adaptability of the soil to grass and the relatively small amount of grain grown make dairying better adapted to the cropping system than any other system of farming except that of stock raising. Dairying will yield a much greater profit than merely raising cattle for the feeder market.

Manure.

The astonishing response that the Ozark soils make to barn yard manure is one of the most important facts to be considered in the farming system. No other system of farming produces as great a quantity of manure per acre of land as does dairying. The physical character of the average Ozark soil, when the stones are removed from it, is well nigh ideal. It is well drained and easily warmed up. Its content of clay insures the retention of moisture and of fertilizer. The soil as a rule does not leach. Soil conditions make the use of manure extremely profitable.

Transportation.

The facilities for transportation over the whole central part of the region are poor. This makes dairying impossible since local markets do not exist. Dairying in the region would have to depend on the great markets. On account of the lack of transportation facilities these cannot be reached. In the Ozark border region, however, and along the three railway lines that cross or approach the central part this system of farming is bound to develop rapidly. For the rest of the region a return to the stock raising of several years ago will prove to be most profitable.

Fruit Growing.

A great deal of the soil of the Ozark region is adapted to the growth of fruit trees, vines and plants. Those best adapted to such plants are the stony and gravelly soils in which the fine grained con-

stituent does not run extremely low. What the lower limit is has not been determined. The limit of profitable growth seems to be where there is not enough clay to prevent leaching. When this occurs the soil does not produce any crop profitably and fruit trees do not constitute an exception. All those gravelly soils having a brown color and a red subsoil seem to be well adapted to the growth of fruit trees and plants. Other soils having blue clay subsoils will often grow the trees fairly well but will not produce good fruit. The clay or silt soils underlain by a layer of cemented gravel or hardpan does not produce either tree or fruit profitably except the small berries and that grown on short lived trees. The growth of berries does not seem to be conditioned by the soil to so great an extent as that of the tree fruits. The tree fruits must have a soil capable of maintaining a tree for many years while the berries may be grown on any soil that has a moderate fertility. The only condition affecting the distribution of the growth of berries in the region is the facility for cheap transportation to market.

The growth of fruit is, however, not dependent solely on the possibility of growing fruit trees. The latter will flourish where the soil conditions are favorable, even though the climatic conditions may not be favorable for the production of fruit. The extremes of temperature in the Ozark region and the frequent occurrence of spring frosts make the growth of peaches and apples a somewhat uncertain industry. In years when the fruit is not killed by late frosts the production of fruit is heavy and the quality good. The frequence with which late frosts occur make the growth of a crop of tree fruits in practically the whole region too uncertain to warrant making it an exclusive industry. It is profitable and probably always will be profitable to carry it on as one part of a varied system of farming.

The southeastern quarter of the region is less subject to late frosts than the rest. Too much emphasis cannot well be placed on the fact that the limitation of the growth of fruit in the Ozark region is not determined, for the region as a whole, by the failure of the soil to grow vigorous trees or to produce good, well colored fruits, but by the frequent occurrence of late frosts in the spring. In addition to this, peaches are often winter killed, owing to the frequent periods of open, warm sunny weather during winter, which cause the buds to swell. They are then killed by the almost invariable severe cold snap in February. The southeastern quarter of the region is more nearly exempt from this condition than the other parts of the region.

The Ozark region is one of stronger climatic contrasts than the northern part of the state. Warm weather during winter warms up the soil rapidly owing to its thorough drainage and the abundance of loose

stone in the soil while cold weather has the opposite effect due to exactly the same soil character. The warm weather of winter is warmer normally and the cold weather is colder than in the clay soils of North Missouri because of the character of the soil. In other words, it is, so far as temperature of the air and soil is concerned, a region with a tendency toward arid conditions; so far as moisture is concerned, however, with its heavy rainfall and its clay subsoil it differs widely from such a region.

Stock Raising.

The original industry of the region was stock raising. Cattle were sold off the range as grass fed cattle. Corn was fed to them only during the winter and then only enough to get them through the winter. The destruction of the range has caused the abandonment, to a great extent, of this industry and no other system of farming has been found that would apply, as well as the old one, to the Ozark Center and the Ozark Plateau areas. Fruit growing has been tried but owing to the climate it has not been found profitable except in small local areas. Cattle feeding cannot be developed because of the lack of an abundant supply of grain. In a large part of the region dairying cannot become an important industry for some time to come because of the lack of facilities for transportation. Because of the small amount of grain soil and the large area of pasture land the two systems of farming that can be carried on are stock raising, not including hogs, except in small numbers, and dairying. This being the case the only feasible system at present for a large part of the area is stock raising. There must be a return to grazing. In order to do this the land must be reset to grass. The brush and timber will have to be killed out and the land brought back to its original condition. This will be found to be the more profitable system in the area of the Plateau, especially. On account, however, of the adaptability of the Ozark center area to the growth of pine timber, the growth of that and the industries based on it will be found to be more profitable than any system of farming except the small amount of grain farming that is and will continue to be carried on in its valleys.

On account of the greater proportion of tillable soil, the smoother topography, better transportation facilities and denser population the farming system on the Ozark border soils is rapidly adjusting itself to dairying and incidental fruit growing, especially in the main area of Springfield soils. Elsewhere in the Ozark border general farming is the rule and is carried on with reasonable profit.

To sum up then: The Ozark Center will gradually evolve into a forested region with grain farming in the valleys and limestone basins. The farming population will be very sparse and its products will be locally consumed by an industrial population depending upon the timber for its livelihood. The stock raised will be sheep, hogs, cattle, horses and mules.

The Ozark Plateau will be found to be better adapted to grazing than to timber growth. It does not grow pine and its oak timber is of very slow growth. Fruit growing will be carried on incidentally along the railways along with dairying. The more important industry, however, will be stock raising.

The Ozark border will engage in general farming, dairying and fruit raising. Dairying will gradually assume greater importance than either of the others and probably of both of them.

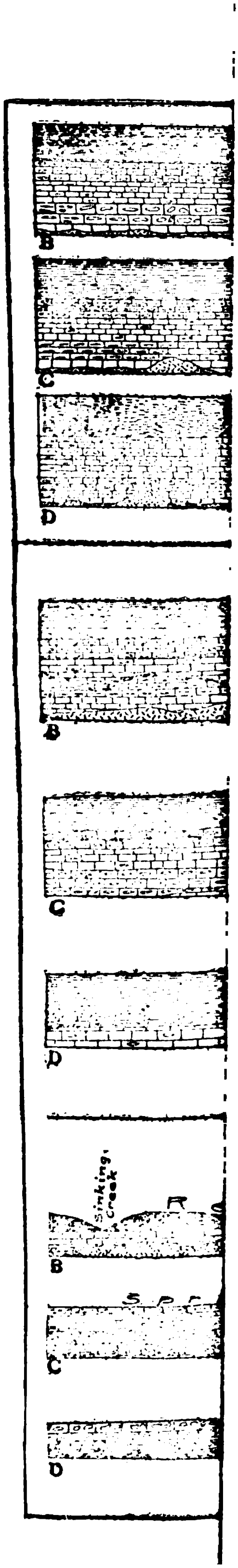
PLATE NO. 1.

A series of geological cross sections across the state from A at the southwest corner of McDonald county to C on the Mississippi river at Ste. Genevieve.

The first section, comprising the top series; A to B, B to C, C to D, shows the region as it is supposed to have been after the rocks had been deposited, but before they had been bowed upward or eroded.

The second section, comprising the middle series of three sections, shows the region after it was bowed upward, but before it was eroded. A heavy line down through this section shows approximately the position of the existing surface in the region and the relation of the amount that has been worn off to that which is left above sea level.

The third section, comprising the last series of three sections, shows the profile of the existing surface, its relation to the geological formations and the relation of the various soil groups to both.


B
C
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Sinking Creek
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RESEARCH BULLETIN NO. 4

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

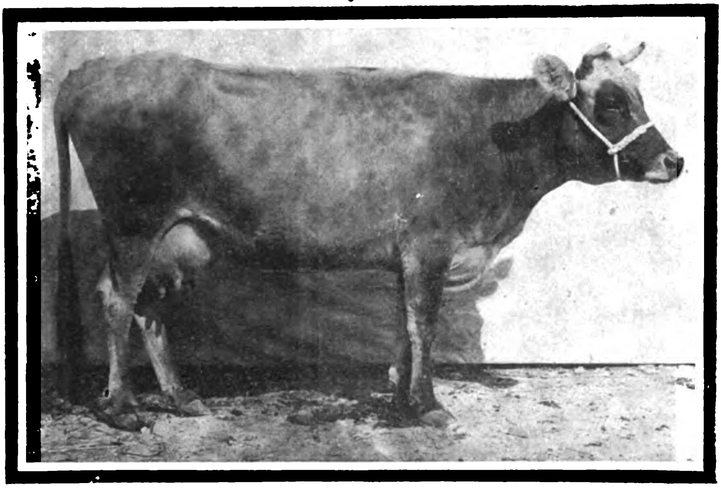
Digestion Trial With Two Jersey Cows on Full Ration and on Maintenance

COLUMBIA, MISSOURI
October, 1911

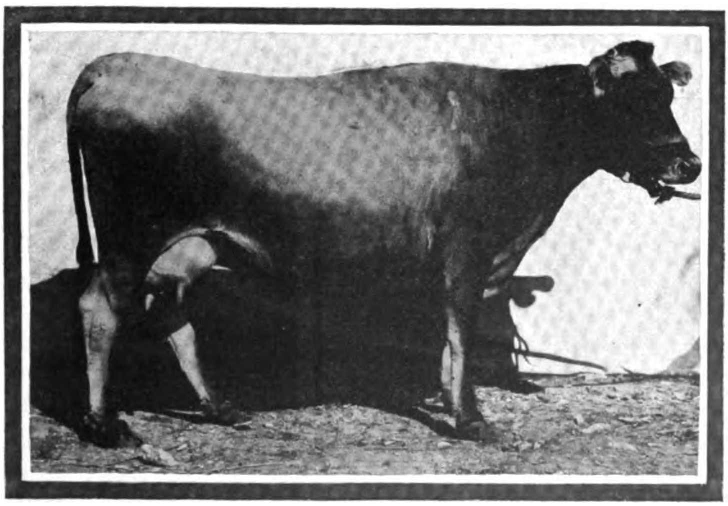
UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station



NO. 27, PEDRO'S RAMAPOSA 181160



NO. 62, PEDRO'S ELF 197242

A DIGESTION TRIAL WITH TWO JERSEY COWS ON FULL RATION AND ON MAINTENANCE.

C. H. ECKLES.

In the course of an investigation already reported[1] digestion trials were conducted with two Jersey cows covering a period of 10 days when on full rations and again when on maintenance. These cows were registered animals known as Pedro's Ramapose 181160 and Pedro's Elf 197242. Table I gives data regarding the history of these animals.

TABLE I.

	No. 27	No. 62
Date of birth	Sept. 4, 1902	May 11, 1903
Age at first calving	29 mo.	18 mo.
Lbs. Milk first lactation period	4552	878
Lbs. fat first lactation period	238.8	44.1
No. days in milk	337	131
Lbs. milk second lactation period	7174	3189
Lbs. fat second lactation period	377	114.8
No. days in milk	365	232
Lbs. milk third lactation period	8522	3188
Lbs. fat third lactation period	469.9	169.3
No. days in milk	365	321

The first digestion trial covered 10 days beginning December 27, 1907. The chemical work was done under the direction of Dr. P. F. Trowbridge, of the Department of Agricultural Chemistry.

The cows were about three months in milk at the time and practically at their maximum production. The digestion trial was carried out in the usual manner. The grain and hay ration for each day for each animal for the entire period was weighed out at the

[1]Research Bulletin No. 2, Mo. Exp. Station.

beginning and a sample taken of each constitutent of the ration. It is not possible to do this with the silage since it will not keep outside the silo. For this reason the silage was weighed out from the silo at each feeding and a composite sample for chemical analysis made by taking a small portion at random from each feed and placing it in a tight glass jar in which sufficient chloroform had been placed to prevent spoiling. The cows were kept in the barn and watered in the manner to be followed during the digestion trial for a week preceding, in order that they might be accustomed to the routine.

Three attendants were provided for each cow, working in 8 hour shifts to collect the dung and urine. A common grain shovel was used for the former and a tin vessel about the size of an ordinary milk pail with a wooden handle was used for collecting the urine. None of the excreta was lost during the 10 days covered by the digestion trial.

Table 2 gives the ration received daily by the two animals.

TABLE 2.

RATION FED PER DAY.

Digestion Trial on Full Ration.

	No. 27		No. 62	
	Lbs.	Kilos	Lbs.	Kilos
Alfalfa Hay	9.0	4.082	6.0	2.585
Silage	35.0	15.875	22.0	10.115
Corn	6.28	2.857	4.0	1.814
Bran	3.14	1.406	2.0	.907
Oilmeal	1.57	.726	1.0	.454

This was the same ration as used throughout the entire investigation of which the digestion trial was one part. It consisted of alfalfa hay of the best quality, corn silage made from well matured corn, and a grain mixture of corn meal 4 parts, wheat bran 2 parts and oilmeal 1 part. The ration of both animals was made up in the same proportion with the only difference being the quantity given which had been adjusted during the several weeks preceding to maintain the cows at uniform weight. It will be noted that No. 27 re-

ceived considerably more than No. 62 which is accounted for by her larger production of milk.

Table 3 gives the chemical analysis and tables 4 and 5 give the amounts of the several constituents in the ration received by the two cows.

TABLE 3.

PERCENTAGE COMPOSITION OF DAILY RATION.

Digestion Trial December 27, 1907 to January 5, 1908.

NO. 27 AND NO. 62.

	Dry Matter	Ash	Nitrogen	Protein	Crude Fibre	Nitrogen free Extract	Fat
Alfalfa Hay.	94.16	8.225	2.030	12.68	36.350	35.33	1.560
Silage......	29.29	1.812	.319	1.99	7.082	17.58	.825
Corn.......	85.04	1.193	1.275	7.97	1.897	69.99	3.993
Bran.......	89.51	6.668	2.328	14.55	8.487	55.05	4.749
Oilmeal.....	90.89	5.343	5.498	34.36	7.975	36.47	6.736
Refused....	94.53	7.013	1.461	9.13	41.673	34.77	1.943

TABLE 4.

COMPOSITION OF DAILY RATION FED NO. 27.

Weights in grams.

	Am't Fed	Dry Matter	Ash	Nitrogen	Protein	Crude Fibre	Nitrogen free Ext.	Fat
Alfalfa Hay.	4082.0	3843.6	335.74	82.86	517.88	1483.81	1442.17	63.68
Corn Silage..	15875.0	4649.7	287.66	50.64	316.50	1124.27	2789.83	130.97
Corn.......	2857.0	2429.5	34.08	36.43	227.69	54.20	1999.61	114.08
Bran.......	1406.0	1258.5	93.75	32.73	204.56	119.33	774.00	66.67
Oilmeal.....	726.0	659.8	38.79	39.93	249.50	57.90	264.77	48.90
Total.......	24946.0	12841.1	790.02	242.59	1516.13	2839.51	7270.38	424.30
Refused....	73.2	69.1	5.13	1.06	6.68	30.50	25.45	1.42
Total Rat'n.	24872.8	12772.0	784.89	241.53	1509.45	2809.01	7224.93	422.88

TABLE 5.

COMPOSITION OF DAILY RATION FED NO. 62.

Weights in grams.

	Amt. Fed	Dry Matter	Ash	Nitrogen	Protein	Crude Fibre	Nitrogen free Extract	Fat
Alfalfa Hay....	2585.0	2434.0	212.62	52.48	328.00	939.65	913.28	40.33
Corn Silage...	10115.0	2962.6	183.28	32.27	201.69	716.34	1778.21	83.45
Corn......	1814.0	1542.6	21.64	23.13	144.56	34.41	1269.62	72.43
Bran......	907.0	811.8	60.48	21.11	131.94	76.98	499.30	43.07
Oilmeal....	454.0	412.6	24.26	24.96	156.00	36.21	165.57	30.58
Total......	15875.0	8163.6	502.28	153.95	962.19	1803.59	4625.98	269.86
Refused...	60.7	57.4	4.26	.89	5.54	25.30	21.11	1.18
Total Ration..	15814.3	8106.2	498.02	153.06	956.65	1778.29	4604.87	268.68

Tables 6 and 7 record the amount of milk by milkings for each animal and the totals.

TABLE 6.

YIELD OF MILK AND FAT.

NO. 27.

Date	A. M.			P. M.		
	Lbs. Milk	Per cent Fat	Lbs. Fat	Lbs. Milk	Per cent Fat	Lbs. Fat
Dec. 26............	....	....	....	12.2	6.0	.7320
27............	13.7	5.8	.7946	12.4	5.4	.6696
28............	15.0	5.1	.7650	12.1	4.4	.5324
29............	16.1	5.0	.8050	11.9	5.6	.6664
30............	15.2	4.8	.7296	11.3	5.3	.5989
31............	15.7	4.3	.6751	11.2	5.7	.6384
Jan. 1............	15.0	5.4	.8100	12.1	5.1	.6171
2............	14.3	5.1	.7293	12.3	5.3	.6519
3............	14.3	5.2	.7436	11.7	5.5	.6435
4............	15.0	5.7	.8550	11.1	4.6	.5106
5............	15.5	5.2	.8060	....	....	....
	149.8	5.14	7.7132	118.3	5.29	6.2608

TABLE 7.

YIELD OF MILK AND FAT.

NO. 62.

Date	A. M.			P. M.		
	Lbs. Milk	Per cent Fat	Lbs. Fat	Lbs. Milk	Per cent Fat	Lbs. Fat
Dec. 26	....	....	....	6.1	5.4	.3294
27	7.0	5.6	.3920	5.9	5.0	.2950
28	5.2	3.1	.1612	8.1	5.8	.4988
29	7.7	6.0	.4620	5.6	5.2	.2912
30	7.4	4.9	.3626	6.8	4.7	.3196
31	7.0	5.6	.3920	6.4	5.6	.3584
Jan. 1	7.1	5.1	.3621	5.9	5.0	.2950
2	7.2	5.0	.3600	6.2	4.8	.2976
3	7.4	5.5	.4070	6.1	4.9	.2989
4	6.9	4.6	.3174	5.8	5.5	.3190
5	7.2	5.6	.4032	....	....	....
	70.1	5.16	3.62	63.4	5.2	3.30

Table 8 gives the chemical composition of the milk of each cow and the total of each constituent in both pounds and kilos.

TABLE 8.

COMPOSITION OF MILK.

NOS. 27 AND 62.

	Percentage Composition		Constituents in Lbs. and Kilos			
	No. 27	No. 62	No. 27		No. 62	
			Lbs.	Kilos	Lbs.	Kilos
Total Milk	....	....	268.1	120.61	133.5	60.55
Total Nitrogen	.63	.64	1.69	.76	.85	.39
Total Protein	4.02	4.08	10.78	4.85	5.45	2.47
Fat	5.10	5.10	13.67	6.15	6.81	3.09
Sugar	5.20	5.20	13.94	6.27	6.94	3.15
Ash	.77	.81	2.06	.93	1.08	.49

Table 9 records the daily weights of dung and of urine for each animal and in table 10 is found the result of the analyses.

TABLE 9.

WEIGHTS OF DUNG AND URINE DIGGESTION TRIAL ON FULL RATION.

Date	No. 27		No. 62	
	Weight of fresh dung Kilos	Weight of fresh urine Kilos	Weight of fresh dung Kilos	Weight of fresh urine Kilos
Dec. 27, 1907........	30.245	8.092	12.854	4.632
Dec. 28, 1907........	28.011	9.702	15.559	4.390
Dec. 29, 1907........	30.110	7.159	14.591	4.642
Dec. 30, 1907........	35.608	8.511	14.599	5.440
Dec. 31, 1907........	32.728	6.666	14.153	4.626
Jan. 1, 1908.........	29.935	8.993	15.044	4.451
Jan. 2, 1908.........	31.572	7.589	14.313	4.990
Jan. 3, 1908.........	28.801	6.643	13.973	4.404
Jan. 4, 1908.........	26.638	8.607	14.637	5.376
Jan. 5, 1908.........	28.237	8.482	14.963	4.648
Average............	30.182	7.999	14.469	4.760

TABLE 10.

ANALYSES OF DUNG AND URINE DIGESTION TRIAL ON FULL RATION.

	Composite Sample		Average of Daily Samples	
	No. 27	No. 62	No. 27	No. 62
Dung				
Dry Matter.........	14.95	19.44	....	....
Moisture............	85.05	80.56	....	....
Nitrogen............	·0.33	0.417	0.322	0.425
Protein.............	2.062	2.606	2.013	2.576
Fat................	0.463	.0746	....	....
Crude Fibre........	4.298	5.666	....	....
Ash................	1.574	2.029	....	....
N. free Ex..........	6.552	8.393	....	....
Urine				
Dry Matter.........	7.16	8.03	....	....
Moisture............	92.84	91.97	....	....
Nitrogen............	0.799	1.024	0.783	1.036

The nitrogen was determined separately in both dung and urine daily. A composite sample of each was made by placing an amount equal to 1 part in 50 of the total in an air tight jar with sufficient chloroform added to prevent fermentation. The jars were kept in a temperature of about 5° C. The nitrogen determinations of both urine and dung in the composite sample agrees closely with the averages of the daily analyses.

Tables 11 and 12 give the total amounts of the different nutrients consumed, the amount excreted in the dung and the per cent digested. It will be noted here that while there is some difference regarding the digestibility of the different constituents the average figure was almost exactly the same for both animals.

TABLE 11.

SUMMARY RESULTS AVERAGED BY DAYS.

NO. 27.

Weights in grams.

	Consumed	Excreted in Dung	Per cent Digested
Protein.............	1509.44	622.51	58.75
Fat.................	422.88	139.74	66.95
Crude Fibre.........	2809.01	1297.22	53.82
Nitrogen-free Extract.	7224.93	1977.53	72.62
Total...............	11966.26	4037.00	66.27

TABLE 12.

SUMMARY OF RESULTS AVERAGED BY DAYS.

NO. 62.

Weights in grams.

	Consumed	Excreted in Dung	Per cent Digested
Protein.............	956.65	377.13	60.58
Fat.................	268.68	107.94	59.82
Crude Fibre.........	1778.30	819.81	53.89
Nitrogen-free Extract.	4604.87	1214.38	73.62
Total...............	7608.50	2519.26	66.95

Table 13 gives a comparison of the per cent of the several constituents actually digested and the amount that would be digested according to the average digestion coefficients as given by Jordan.[1]

[1]The Feeding of Animals, p. 427.

TABLE 13

COMPARISON OF AVERAGE AND ACTUAL DIGESTION COEFFICIENTS.

NO. 27 AND NO. 62.

On Full Ration.

	Protein		Crude Fibre		Nitrogen free Extract		Fat	
	Average	Actual	Average	Actual	Average	Actual	Average	Actual
No. 27......	70.2	58.75	53.9	53.82	76.6	72.62	78.0	66.95
No. 62......	70.2	60.58	53.9	53.89	76.6	73.62	78.0	59.82

Using average figures No. 27 should have digested 70.81 per cent of the ration while she digested 66.27 as found by trial.

The figures for No. 62 by average coefficients is 70.79 while by trial the figure was 66.95.

On Maintenance.

	Protein		Crude Fibre		Nitrogen free Extract		Fat	
	Average	Actual	Average	Actual	Average	Actual	Average	Actual
No. 27......	69.4	67.32	52.7	55.33	74.6	82.12	77.0	73.17
No. 62......	68.7	65.54	53.8	52.06	75.4	80.99	76.7	73.92

When on maintenance No. 27 digested 73.79 per cent and No. 62 72.19 per cent of the entire ration. The average digestion coefficient for the same ration are 69.1 for No. 27 and 69.7 for No. 62.

The first half of the table gives this comparison for the digestion trial made while the cows were on full ration and the second half for the digestion trial made for the same animals when on maintenance. The columns headed "Average" is the digestion coefficient of this ration calculated by applying average figures of digestibility to the data given in Tables 4 and 5. The columns headed "Actual" gives the coefficient of digestion as actually determined for No. 27 and No.62. When the cows were on full ration it will be noted the coefficient was decidedly lower for both cows than the average with the exception of the crude fibre. The data for the second digestion trial indicates

the same cows on a maintenance ration of the same composition as in the first were able to show a coefficient of digestibility fully as high as the averages ordinarily used. This seems to indicate the depression in the digestion coefficient with both animals when on the full ration was due to the amount of the ration consumed. When both were on maintenance No. 27 had on the whole a higher digestion coefficient than No. 62 while on a full ration the reverse was true. That is, on a full ration when No. 27 was consuming 50% more feed than No. 62 her coefficient of digestion was lower, while when both were dry and farrow she was able to digest a slightly higher per cent of her food. The general tendency of the digestion trials carried on at this Experiment Station with steers by Dr. P. F. Trowbridge the results of which have not as yet been published also indicate that the plane of nutrition has a decided influence on the digestion coefficient.

Since most of the digestion trials upon which the average digestion coefficients are based were made with animals at or near maintenance conditions it is not surprising that animals on full ration are not able to make as good use of the food as those on a lower plane of nutrition. While the results given are entirely too few upon which to base a conclusion it at least is justifiable to raise the question if the digestion coefficients for use in making calculations regarding the feeding of dairy cows should not be determined by using cows that are producing large quantities of milk and for this reason are receiving a heavy ration rather than by making use of coefficients of digestibility from trials with steers under maintenance conditions.

Table 14 gives the nitrogen balance. The outgo of nitrogen in milk, urine and dung agrees closely with that taken in by the food in both animals.

TABLE 14.

DAILY NITROGEN BALANCE.

Weights in grams.

	No. 27	No. 62
Dung	99.60	60.34
Urine	63.90	48.74
Milk	76.00	39.00
Total	239.50	148.08
Consumed in Feed	241.53	153.06

DIGESTION TRIAL ON MAINTENANCE

Abuut 13 months later, a digestion trial was again made with the same two cows. This time they were dry and farrow. The trial lasted 10 days beginning January 28, 1909. No. 62 had been on maintenance 150 days and No. 27, 90 days at the beginning of this trial. Data regarding the maintenance period is given in detail in another part of this publication. The ration fed the animals was the same as given when in milk at the time of the first trial. The same grain mixture was used and practically the same ratio between the grain, hay and silage was maintained. For each pound of grain, each cow consumed, she also received one pound of alfalfa hay and four pounds of silage. The amount given was of course such as was found by trial during the preceding months to be necessary for maintenance.

Table 15 gives the ration fed and Table 16 the chemical composition of each constituent of the ration.

TABLE 15.

RATION FED PER DAY, DIGESTION TRIAL ON MAINTENANCE.

	No. 27		No. 62	
	Lbs.	Kilos	Lbs.	Kilos
Alfalfa Hay	3.2	1.451	2.8	1.270
Silage	12.8	5.806	11.2	5.080
Corn	1.83	.830	1.6	.726
Bran	.91	.415	.8	.363
Oilmeal	.46	.207	.4	.181

TABLE 16.

PERCENTAGE COMPOSITION OF RATION FED, DIGESTION TRIAL ON MAINTENANCE.

NO. 27 AND NO. 62.

	Dry Matter	Ash	Nitrogen	Protein	Crude Fibre	N. free Extract	Fat
Alfalfa Hay.	94.21	8.960	2.250	14.06	32.97	35.84	2.380
Silage......	30.192	1.869	.227	1.42	7.00	18.23	1.676
Corn.......	94.07	1.190	1.415	8.84	2.03	78.24	3.770
Bran.......	90.285	7.293	2.335	14.59	10.25	53.50	4.645
Oilmeal.....	93.45	5.540	5.440	34.00	8.03	38.57	7.310

Tables 17 and 18 give the total amounts of each constituent of the ration received by the two cows.

TABLE 17.

COMPOSITION OF RATION, TEN DAYS DIGESTION TRIAL ON MAINTENANCE.

NO. 27.

Weights in grams.

	Dry Matter	Ash	Nitrogen	Protein	Crude Fibre	N. free Extract	Fat
Alfalfa. ...	13674.49	1300.53	326.58	2040.79	4785.56	5202.14	345.45
Silage	17529.49	1085.13	131.80	824.44	4064.17	10584.25	973.08
Corn	7807.20	98.72	117.39	733.38	168.41	6493.92	312.77
Bran	3743.04	302.35	96.80	604.87	424.94	2218.00	192.57
Oilmeal ...	1937.13	114.84	112.77	704.79	166.45	799.52	151.53
Total	44691.55	2901.57	785.34	4908.27	9609.53	25297.86	1975.40

TABLE 18.

COMPOSITION OF RATION, TEN DAYS DIGESTION TRIAL ON MAINTENANCE.

NO. 62.

Weights in grams.

	Dry Matter	Ash	Nitrogen	Protein	Crude Fibre	N. free Extract	Fat
Alfalfa.....	11965.14	1137.96	285.76	1786.00	4187.35	4551.86	302.27
Silage.....	15338.14	949.49	115.32	720.75	3556.14	9261.20	851.44
Corn......	6827.04	86.36	102.69	641.81	147.33	5678.19	273.60
Bran......	3276.17	264.64	84.73	529.56	371.94	1941.35	168.55
Oilmeal...	1695.56	100.52	98.70	616.88	145.69	699.81	132.63
Total.....	39102.05	2538.97	687.20	4295.00	8408.45	22132.41	1728.49

Table 19 gives the weights of dung and urine by days.

TABLE 19.

Weight in pounds.

Date	No. 27		No. 62	
	Weight of fresh dung Kilos	Weight of fresh urine Kilos	Weight of fresh dung Kilos	Weight of fresh urine Kilos
Jan. 29, 1909	6.996	3.683	6.732	3.842
Jan. 30, 1909	7.471	3.279	5.765	3.847
Jan. 31, 1909	5.419	2 950	4.851	4.079
Feb. 1, 1909	5.905	3.205	4.472	3.742
Feb. 2, 1909	6.025	3.609	4.789	3.021
Feb. 3, 1909	7.017	3.377	5.073	3.160
Feb. 4, 1909	6.528	3.667	5.200	3.163
Feb. 5, 1909	6.364	3.277	6.649	3.942
Feb. 6, 1909	6.777	3.743	6.010	3.586
Feb. 7, 1909	7.765	4.348	6.149	4.305
Average	6.627	3.514	5.569	3.669

The excreta was handled in the same manner as described for the first trial. Only composite samples were taken in this case since the analyses of the daily and of the composite samples had been found in the first trial to check closely. The analyses of the composite samples of dung and urine is found in Table 20.

TABLE 20.

COMPOSITION OF DUNG AND URINE DIGESTION TRIAL ON MAINTENANCE.

	Composite Sample	
	No. 27	No. 62
Dung		
Dry Matter	18.998	20.837
Moisture	81.002	79.163
Nitrogen	0.387	0.424
Protein	2.419	2.650
Fat	0.799	.807
Crude Fibre	.6.473	7.217
Ash	2.487	2.630
Nitrogen free Extract	6.82	7.531
Urine		
Nitrogen	1.523	1.360

The nitrogen balance as given below shows a reasonably close agreement.

	Weights in Grams No. 27	Weights in Grams No. 62
Dung	25.65	23.61
Urine	53.52	49.90
Total	79.17	73.51
Consumed in Feed	78.53	68.7

Tables 21 and 22 give a summary of the results of this digestion trial.

TABLE 21.

SUMMARY OF DIGESTION TRIAL ON MAINTENANCE.

NO. 27.

	Consumed Grams	Excreted in Dung Per cent	Excreted in Dung Weight Grams	Per cent Digested
Protein	4908.27	2.419	1604.19	67.32
Fat	1975.40	.799	529.92	73.17
Crude Fibre	9609.53	6.473	4293.08	55.33
N. free Ex	25297.86	6.82	4523.23	82.12
Total	41791.06	....	10950.42	73.79

TABLE 22.

SUMMARY OF DIGESTION TRIAL ON MAINTENANCE.

NO. 62.

	Consumed Grams	Excreted in Dung Per cent	Excreted in Dung Weight Grams	Per cent Digested
Protein	4295.0	2.65	1480.25	65.54
Fat	1728.49	.807	450.78	73.92
Crude Fibre	8408.45	7.217	4031.34	52.06
N. free Ex	22132.41	7.531	4206.18	80.99
Total	36564.35	....	10168.55	72.19

The second column, headed per cent, in both tables refers to the composition of the dung, the weights of which are found in Table 19. The third column is the weight of the constituents excreted and the fourth column the per cent digested. No. 27 shows a higher

per cent of each constituent digested with an average of 7.5 more for the entire ration when on maintenance. No. 62 also has digested a larger per cent of each constituent and an average of 5.24 per cent higher when on maintenance.

Table 23 is included as a matter of interest. It gives the amount of water consumed daily by each cow while on full ration producing and again when dry and on maintenance. It illustrates the increased demands for water by the cow in milk and consuming a large ration.

TABLE 23.

WATER CONSUMED DURING DIGESTION TRIALS.

Weights in Pounds.

Day	No. 27		No. 62	
	First	Second	First	Second
1	94	0	68	23
2	82	0	30	0
3	77	20	37	0
4	81	23	43	28
5	82	17	30	17
6	82	15	46	0
7	73	20	32	30
8	77	18	46	18
9	65	17	40	0
10	60	17	29	12
Average	77.3	14.7	40.1	12.8

SUMMARY AND CONCLUSIONS.

Complete data is given of a digestion trial made with two Jersey cows when at the maximum yield of milk and repeated with the same animals when dry and on maintenance. The ration used was the same in both trials except in quantity.

When on full ration the per cent digested was lower with both animals and for each constituent of the ration than the average figures in common use.

The cow which received the most liberal ration digested 66.27 per cent of the entire ration. According to the digestion coefficients in common use she should have digested 70.81 per cent. The same cow on maintenance digested 73.79 per cent of the ration. The average figures for the same ration are 69.1 per cent. The second cow receiving about 50 per cent less feed, during the trial when in milk digested 66.95 per cent of the ration. On maintenance the same animal digested 72.19. According to the average figures in use she should have digested 70.79 per cent in the first trial and 69.7 for the second.

These results suggest that the average digestion coefficients in use are somewhat high as applied to cows producing large quantities of milk which requires a heavy ration and that accurate figures for this purpose should be obtained from experiments with cows in milk.

RESEARCH BULLETIN NO. 5.

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

Maintenance Trials With Five Jersey Cows

COLUMBIA, MISSOURI
October, 1911

UNIVERSITY OF MISSOURI

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MAINTENANCE TRIALS WITH FIVE JERSEY COWS.

C. H. Eckles.

The two cows, data concerning which is given in connection with a report on digestion trials,[1] and three other cows of the same breed were kept for periods of from 120 to 180 days on maintenance. The special object in determining the maintenance of two of the animals, Nos. 27 and 62, has been given in another publication.[2] The other three animals were used in another investigation having for its object the determination of the comparative cost of producing solids in the form of milk and live weight on the animal body by the same animals. Details of this latter investigation have not as yet been put in print.

The five Jersey cows used were registered animals of that breed and were all half-sisters, having the same sire. Details regarding two of these animals will be found in another publication.[1] Below is given data regarding the other three. The figures given for the yield of milk and the yield of fat is for the period of lactation, 365 days in length, which closed shortly before the maintenance trial was begun.

	No. 4	No. 63	No. 43
Name and Number	Pedro's Alphea Elf 168587	Pedro's Grace Briggs 197836	Miss Missouri 181159
Age	8 yrs. 6 mo.	5 yrs. 6 mo.	6 yrs. 3 mo.
Weight	792 lbs.	889 lbs.	736 lbs.
Yield Milk	6773 lbs.	6077 lbs.	8137 lbs.
Yield Fat	376 lbs.	370 lbs.	398 lbs.

The ration fed four of the animals, Nos. 27, 62, 4, and 63, was exactly the same except the quantity was varied as was found necessary to maintain a uniform weight. The ration used was of the same composition as given while the same animals were producing

1. Research Bul. No. 4 Mo. Exp. Sta.
2. Research Bul. No. 2 Mo. Exp. Sta.

milk since it was desired to determine maintenance requirements in terms of the ration fed while in milk. No attempt was therefore made to determine the minimum protein requirement. Had the object in view been the maintenance of these animals with the minimum protein or at the least cost financially a ration with a larger amount of roughness would have been used. The same grain mixture was employed as was used when the cows were in milk, namely, 4 parts of corn, 2 parts bran, 1 part oilmeal. The proportion used was 1 pound of this grain mixture to 1 pound of alfalfa hay and 4 pounds of silage.

On account of the nature of the investigation in which No. 43 was included she received while on maintenance the ration that has been used in carrying on investigations with growing and fattening steers at this Experiment Station. Her grain mixture consisted of 8 parts of corn to 1 part of oilmeal and 1 pound of alfalfa hay was fed to each 2½ pounds of grain. No. 43 was put on this ration a sufficient length of time before the data on maintenance was taken to adjust her ration to the maintenance point.

The cows were all farrow while these maintenance trials were conducted. The animals were kept nights and during stormy weather in the dairy barn in which the temperature varied considerably. In daytime and during fair weather the animals were turned into a dry lot with no opportunity to secure additional feed. Each animal was weighed daily, in the morning following feeding and before receiving water. The usual difficulties were experienced in maintaining the animals at uniform weight on account of the variations from day to day which is generally assumed to be due to the difference in the contents of the alimentary canal, and to some extent to the amount of water drunk. The average weights by ten days periods are given for each animal in the tables which follow. Apparently there was a gain of about 15 pounds in 160 days with No. 27, and about the same amount with No. 62 in 180 days, with a loss of the same amount for No. 63 in 120 days, a small gain for No. 4 amounting to 14 pounds in 150 days, while No. 43 apparently closed the 130 days trial at the same point at which she began.

The periods as used in the tables are uniformly for ten days. Tables 1, 2, 3, 4, and 5 give the amount of hay, grain, and silage consumed by each animal, also the average weight for each 10 day period. The feedstuffs used were all subjected to chemical analysis, results of which are given in Table 6. In this table the analysis of each different lot of feed is given. By referring to the number given under the heading "Lot" and the tables which follow it is possible to cal-

culate the amount of each chemical constituent received by each animal as may be desirable.

In calculating the results the composition of the grain mixtures fed is first calculated and then used as one figure. The proportion of the feeds used in the grain mixtures fed at different times is as follows:

FEEDS USED IN THE GRAIN MIXTURES.

	CORN		BRAN		OILMEAL	
	Parts	Lot	Parts	Lot	Parts	Lot
Grain Mixture A.....	4	1	2	1	1	1
Grain Mixture B.....	4	2	2	2	1	1
Grain Mixture C.....	4	1	2	1	1	1
Grain Mixture D....	8	1	0		1	1
Grain Mixture E.....	8	1	0		1	3

Table 7 gives the composition of the grain mixtures derived in the manner explained. Tables 8, 9, 10, 11, and 12 give the composition of the rations fed the individual animals together with the totals and the amount of each constituent received per day.

In making further calculations use is made of the digestion coefficients as given in Table 13, employing the average figures as given by Jordan.[1] The digestion coefficient is calculated for the grain mixtures in order that it may be employed as a single figure.

Tables 14 and 15 give the digestible nutrients in the rations calculated according to the average digestion coefficients as given. The total received per day, and per day per thousand pounds live weight is also included. As was previously stated no attempt was made to determine the minimum protein requirement but rather to determine the proportion of a normal ration that will be used for maintenance.

COMPARISON WITH ARMSBY'S STANDARD.

In order that the maintenance requirement as found for these five cows may be compared with that suggested by Armsby the ration received by each cow is calculated from the tables pre-

[1]Jordan, "Feeding of Farm Animals."

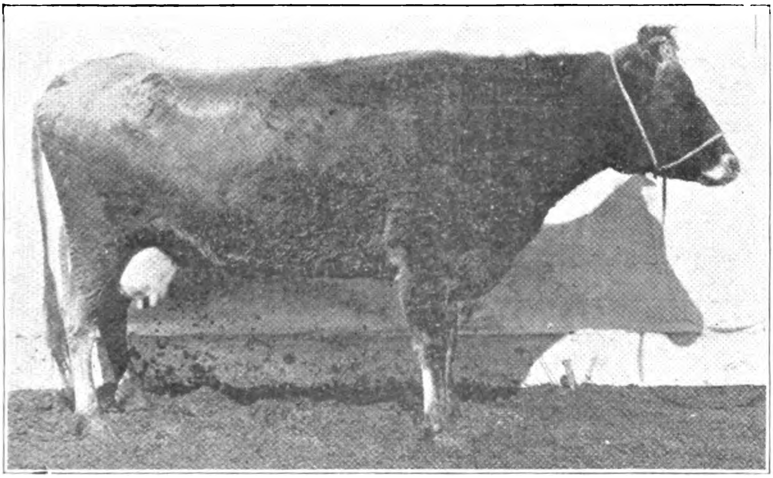
pared by him[1] and the amount of dry matter, digestible protein and energy value expressed in therms is given, with his maintenance figures for an animal of the same weight below for comparison. These calculations are found in Tables 16 and 17. It will be observed from this data that the maintenance requirements of three of these animals expressed in therms agrees reasonably close with the figures presented by Armsby. Altho there is considerable variation the average for the four receiving the normal ration is 6.08 therms per 1000 pounds as compared with 6.00 as given by Armsby. Cow 43 shows considerable higher requirements. The latter animal, as previously explained, received the ration as ordinarily used for fattening steers. No. 62 and No. 63 both show somewhat less maintenance requirement than called for by Armsby's tables. These two animals as shown by the illustrations carried more flesh in proportion to the size of their frame than did No. 27 or No. 4 which may be of some significance. No. 4 was an animal equal in size as far as skeleton and body is concerned to any of the others but carried considerably less flesh.

Since No. 43 received a ration which is quite different in composition from that usually fed a cow producing milk it is perhaps as well to leave her out in preparing an average.

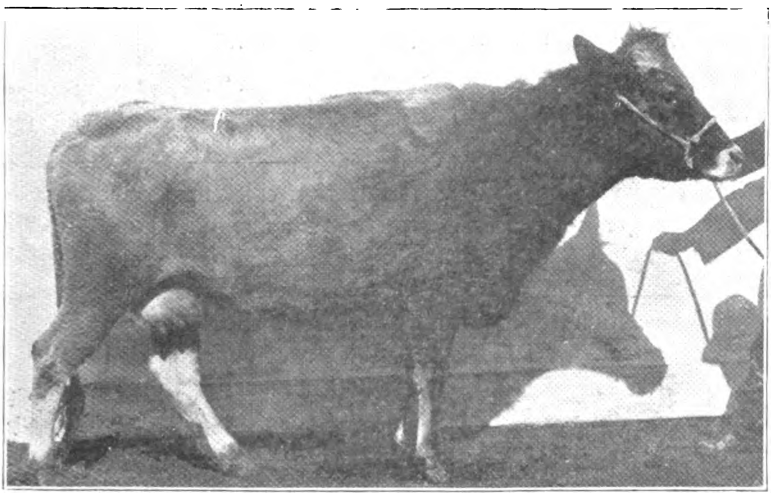
COMPARISON WITH HAECKER'S STANDARD.

A comparison was also made of the maintenance requirements as found for these five cows as compared with the maintenance ration as given by Haecker.[2] Since a complete statement is not given of the ration the animals received upon which he based his standard it is impossible to make an entirely satisfactory comparison. His ration of maintenance calls for .7 lbs. of digestible protein, 7 lbs. digestible carbohydrates, .1 lb. digestible fat. In order to get the two rations on a comparable basis the energy value is calculated according to Kellner's figures as quoted by Armsby,[3] except the fat is given a value of 2100 C. per pound intermediate between coarse feeds and grains. This is done since Haecker does not state how much of the fat in the ration he used came from the roughness and how much from the grain.

[1]Farmers' Bulletin 346 U. S. Dept. Agric.
[2]Bulletin 79 Minn. Exp. Sta.
[3]Bul. 71 Pa. Exp. Sta. p. 14.



NO. 4. PEDRO'S ALPHEA ELF 168587.
Photographed After 4 Months on Maintenance.



NO. 43. MISS MISSOURI 181159.
Photographed After 4 Months on Maintenance.

HAECKER'S MAINTENANCE RATION.

1000 lb. cow.

Digestible Nutrients	lbs.	Energy Value Per lb. in Therms	Total Energy Value in Therms
Protein..............	0.7	1.016	.711
Carbohydrates........	7.0	1.071	7.497
Fat..................	0.1	2.100	.210
Total			8.418

On the same basis the rations fed the five Jersey cows had the following value:

DIGESTIBLE NUTRIENTS PER DAY PER 1000 LBS. WEIGHT.

	Lbs. Digestible Protein	Lbs. Digestible Carbohydrates	Lbs. Digestible Fat	Energy Value per 100 lbs. weight. Themes
No. 27.......	.949	6.005	.374	8.180
No. 62.......	.839	5.210	.309	7.081
No. 63.......	.868	5.368	.318	7.299
No. 4.......	1.111	7.018	.442	9.573
No. 43.......	1.122	6.993	.492	9.663

The energy value of Haecker's ration calculated on this basis is 8.42 therms per 1000 pounds while the average required to maintain the four Jersey cows receiving the normal dairy ration was 8.61 per 1000 pounds which shows a rather close agreement.

Two digestion trials were conducted with Nos. 27 and 62. In Research Bul. No. 4, Table 13 is shown a comparison of the per cent digested while on maintenance and when receiving full ration. It is pointed out in that connection that the per cent digested when on maintenance is considerably higher than when receiving a full ration. Under the latter conditions the coefficient of digestibility agrees reasonably well with the averages as ordinarily given.

In Table 18 under the heading "Average" is found the amount of the several constituents digested applying the average figures given by Jordan. Under the heading "Actual" is given the amounts digested as found by trial. The average digestibility of the total ration by average digestion coefficients should be 69.1 per cent while No. 27 showed an average of 73.79 and No. 62, 72.19 per cent.

MAINTENANCE REQUIREMENTS OF NO. 27 AND NO. 62 CALCULATED FROM DIGESTION TRIAL.

Since data is available regarding the chemical composition of the food consumed on maintenance, also a digestion trial for these two animals when on maintenance it is possible to calculate the requirements of these two animals more accurately than by using average figures as is done in Tables 14-17.

In making these calculations the method followed by Armsby[1] in preparing his table of "Production Values" of feed stuffs was used except that the amount to be subtracted for crude fibre in silage was made in accordance with that suggested by Kellner [2] and more recently adopted by Dr. Armsby.[3]

In making these calculations it was assumed that the per cent of each constituent digested varied from average figures[4] in the same ratio that the total amount of that constituent digested according to the digestion trial varied from what would have been digested according to average digestion coefficients. For example in Table 13. Research Bul. No. 4, cow No. 27 is seen to have digested 67.32 per cent of the protein in the ration while according to the average digestion coefficients she should have digested 69.4. That is, the per cent digested was 97.0 per cent of what would be expected from the average figures of digestion. It was therefore assumed that the digestion coefficient for the protein in each food stuff was 97.0 per cent of the average figures. The same plan was followed with each constituent. The amount of amid free protein was calculated by assuming that the same proportion of the digestible protein was in the amid form as was assumed by Dr. Armsby in preparing his table on "Production Values." The value of the ration in therms was calculated by finding the energy value of each constituent of the ration as outlined in Pa. Bulletin No. 71 using the factors for each feed as given by Kellner.[5]

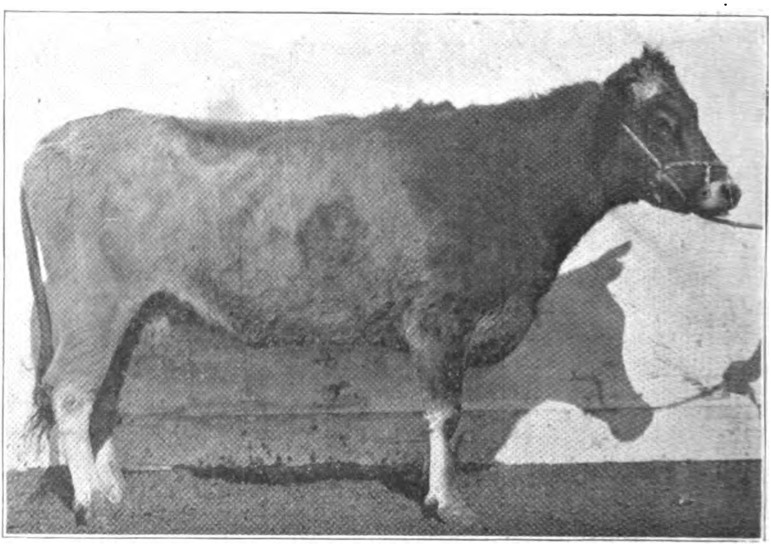
According to this method of calculation the energy value of the ration required for maintenance by the two animals was as follows:

1. Bul. 71 Pa. Exp. Station p. 14.
2. Die Ernahrung der landwirthschaftlichen Nutztiere p. 581.
3. Farmers' Bulletin 346 U. S. Dept. Agric.
4. Average digestion coefficients used are from Jordan's—"The Feeding of Animals."
5. Loc. cit. p 582.

	Live Weight Lbs.	Energy Value Maintenance Ration. Therms.	Armsby's Standard. Therms.
No. 27	890	6.43	5.55
No. 62	917	5.56	5.56

The average for the two is 6.00 therms or about .5 therms higher than the standard suggested by Armsby.[1]

By comparing with Table 16 where the calculations are based upon average figures for both composition and digestion it will be seen that the results are higher in this case when based upon the results of the digestion trial and analysis of the food consumed. This results from the fact that the per cent digested by these two cows was above the average figures.



NO. 63. PEDRO'S GRACE BRIGGS 197836.
Photographed After 4 Months on Maintenance.

The average energy value of the ration given two cows with which a digestion trial was made that admits of more accurate calculation was 6.00 therms while for animals of this weight the energy value required is estimated at 5.56 therms by Armsby.

The general conclusion from the results with four Jersey cows is that the average maintenance requirements of these animals is quite close to the standards suggested by Armsby and by Haecker.

TABLE 1.

NO. 27.

SUMMARY OF FEED CONSUMED ON MAINTENANCE.

October 30, 1908 to April 7, 1909.

Period	Grain	Alfalfa Hay	Silage	Aver. Weight
1..........	40	40	160	881.1
2..........	37.5	37.5	150	889.5
3..........	33	33	132	887.4
4..........	33	33	132	884.2
5..........	33	33	132	888.9
6..........	32.4	32.4	129.6	895.7
7..........	31	31	124	891.4
8..........	31	31	124	871
9..........	31	33	132	882.4
10..........	32	32	128	888.9
11..........	32	32	128	898.5
12..........	32	32	128	891.1
13........	32	32	128	902.8
14..........	32	32	128	891.1
15..........	32	32	128	889.4
16..........	32	32	128	896.7
Total........	525.9	527.9	2111.6	889.4
Per day......	3.29	3.30	13.20	

TABLE 2.

NO. 62.

SUMMARY OF FEED CONSUMED ON MAINTENANCE.

August 31, 1908 to February 26, 1909.

Period	Grain	Alfalfa Hay	Silage	Aver. Weight
1..........	30	30	123	906
2..........	30	30	120	904.5
3..........	30	30	120	911
4..........	30	30	120	911
5..........	30	30	120	913.5
6..........	31	31	124	904
7..........	30	30	120	908.9
8..........	30	30	120	911.6
9..........	30	30	120	917.4
10..........	30	30	120	921.2
11..........	29.4	29.4	117.6	929.2
12..........	28	28	112	924.6
13..........	28	28	112	923.7
14..........	28	28	112	924.5
15..........	28	28	112	918.3
16..........	28	28	112	922.4
17..........	28	28	112	924.1
18..........	28	28	120	924.4
Total........	526.4	526.4	2116.6	916.7
Per day......	2.92	2.92	11.76	

TABLE 3.

NO. 63.

SUMMARY OF FEED CONSUMED ON MAINTENANCE.

October 20, 1908 to February 16, 1909.

Period	Grain	Alfalfa Hay	Silage	Aver. Weight
1..........	32	32	136	895
2..........	32	32	132	918.6
3..........	30	30	120	878
4..........	30	30	120	891.7
5..........	30	30	120	882.3
6..........	30	30	120	888.4
7..........	29.4	29.4	117.6	900.1
8..........	28	28	112	883.9
9..........	28	28	112	874.5
10..........	28	28	112	882.7
11..........	28	28	112	885.7
12..........	28	28	112	881.8
Total........	353.4	353.4	1425.6	888.6
Per day......	2.95	2.95	11.88	

TABLE 4.

NO. 4.

SUMMARY OF FEED CONSUMED ON MAINTENANCE.

October 20, 1908, to March 18, 1909.

Period	Grain	Alfalfa Hay	Silage	Aver. Weight
1.........	38	38	152	794.5
2..........	36.1	36.1	144.4	819.1
3..........	30	30	120	799.4
4..........	30	30	120	806.4
5..........	30	30	120	792.5
6..........	31	31	124	794.2
7..........	31	31	124	785.6
8..........	31	31	124	788.4
9..........	31	31	124	772.5
10..........	33	33.1	132	766
11..........	35.8	35.8	143.2	768.4
12..........	40	40	160	786
13..........	40	40	160	796.8
14..........	37.3	37.3	158.8	803.4
15..........	39.7	39.7	160	810.7
Total........	513.9	514	2066.4	792.3
Per day......	3.43	3.43	13.78	

TABLE 5.

NO. 43.

SUMMARY OF FEED CONSUMED ON MAINTENANCE.

November 9, 1908, to March 18, 1909.

Period	Grain	Hay	Aver. Weight
1	67	26.8	733.2
2	70	28	748.4
3	61	24.4	743
4	60	24	736.9
5	60	24	752.4
6	60	24	730
7	60	24	730
8	60	24	734.1
9	60	24	729.3
10	60	24	732.2
11	60	24	728.8
12	66	26.4	728.4
13	79	31.6	735.2
Total	823	329.2	735.5
Per day	6.33	2.53	

TABLE 6.

CHEMICAL ANALYSIS OF FEED USED IN MAINTENANCE TRIALS.

	Lot	Per cent Dry Matter	Per cent Ash	Per cent Protein	Per cent Crude Fibre	Per cent Nitrogen Free Extract	Per cent Ether Extract
Hay..........	1	95.06	9.03	16.388	28.72	38.202	2.72
Hay..........	2	91.09	7.87	14.75	31.60	34.80	2.07
Hay..........	3	94.21	8.96	14.063	32.99	35.84	2.38
Silage........	1	39.86	2.539	3.465	10.024	22.404	1.423
Silage........	2	29.99	1.967	2.432	7.447	17.129	1.017
Silage........	3	30.19	1.869	1.421	6.999	18.227	1.676
Corn.........	1	90.25	1.50	8.906	1.813	72.804	5.230
Corn.........	2	94.07	1.19	8.844	2.030	78.236	3.770
Bran.........	1	89.82	6.75	14.440	9.190	52.460	6.980
Bran.........	2	89.28	6.293	14.594	10.250	53.503	4.645
Oilmeal.......	1	90.89	5.363	34.363	7.975	36.450	6.736
Oilmeal.......	2	93.45	5.54	34.000	8.03	38.570	7.310
Oilmeal.......	3	91.50	5.385	34.725	8.185	36.270	6.932

TABLE 7.

COMPOSITION OF THE GRAIN MIXTURES.

Lot	Per cent Dry Matter	Per cent Ash	Per cent Protein	Per cent Crude Fibre	Per cent Nitrogen Free Ext.	Per cent Ether Extract
A	90.22	3.55	14.124	4.798	61.798	5.94
B	92.90	3.555	14.074	5.235	65.504	4.526
C	90.31	3.555	14.175	4.831	61.772	5.973
D	90.32	1.929	11.743	2.508	68.764	5.397
E	90.39	1.932	11.775	2.521	68.744	5.419

TABLE 8.

COMPOSITION OF THE GRAIN MIXTURES.

NO. 27.

Weights in Pounds.

	Lot	Lbs. Fed	Dry Matter	Ash	Protein	Crude Fibre	Nitrogen free Extract	Ether Extract
Alfalfa Hay.	2	527.9	480.86	41.55	77.87	166.82	183.71	10.93
Silage. .	2	1215.6	364.56	23.91	29.56	90.53	208.22	12.36
Silage. .	3	896.0	270.50	16.75	12.73	62.71	163.31	15.02
Grain. .	A	301.9	272.37	10.72	42.64	14.49	186.56	17.93
Grain. .	B	32.0	29.73	1.14	4.50	1.68	20.96	1.45
Grain. .	C	192.0	173.36	6.83	27.22	9.28	118.60	11.47
Total 160days	....	....	1591.38	100.90	194.52	345.51	881.36	69.16
Per day	....	....	9.95	.63	1.22	2.16	5.51	.43

TABLE 9.

COMPOSITION OF RATION FED.

NO. 62.

Weights in Pounds.

	Lot	Lbs. Fed	Dry Matter	Ash	Protein	Crude Fibre	Nitrogen free Extract	Ether Extract
Alfalfa Hay.	1	30.0	28.52	2.71	4.92	8.62	11.46	.82
Alfalfa Hay..	2	468.4	426.67	36.86	69.09	148.01	163.00	9.70
Alfalfa Hay..	3	28.0	26.38	2.51	3.94	9.24	10.04	.67
Silage. .	1	123.0	49.03	3.12	4.26	12.33	27.56	1.75
Silage. .	2	1649.6	494.72	32.45	40.12	122.85	282.56	16.78
Silage. .	3	344.0	103.85	6.43	4.89	24.08	62.70	5.77
Grain. .	A	498.4	449.66	17.69	70.39	23.91	307.99	29.60
Grain. .	B	28.0	26.01	1.00	3.94	1.47	18.34	1.27
Total 180days	....	....	1604.84	102.77	201.55	350.51	883.65	66.36
Per day			8.92	.57	1.12	1.95	4.91	.37

TABLE 10.

COMPOSITION OF RATION FED.

NO. 63.

Weights in Pounds.

	Lot	Lbs. Fed	Dry Matter	Ash	Protein	Crude Fibre	Nitrogen free Extract	Ether Extract
Alfalfa Hay..	2	353.4	321.91	27.81	52.13	111.67	122.98	7.32
Silage. .	2	1201.6	360.36	23.64	29.22	89.48	205.82	12.22
Silage. .	3	224.0	67.63	4.19	3.18	15.68	40.83	3.75
Grain. .	A	353.4	318.84	12.55	49.91	16.96	218.39	20.99
Total 120days	....	....	1068.74	68.19	134.44	233.79	588.02	44.28
Per day	....	....	8.22	.52	1.03	1.80	4.52	.34

TABLE 11.

COMPOSITION OF RATION FED.

NO. 4.

Weights in Pounds.

	Lot	Lbs. Fed	Dry Matter	Ash	Protein	Crude Fibre	Nitrogen free Extract	Ether Extract
Alfalfa Hay..	2	514.0	468.20	40.45	75.82	162.42	178.87	10.64
Silage. .	2	1284.4	385.19	25.26	31.24	95.65	220.00	13.06
Silage. .	3	782.0	236.09	14.62	11.11	54.73	142.54	13.11
Grain. .	A	444.6	401.14	15.78	62.80	21.33	274.75	26.41
Grain. .	C	69.3	62.59	2.46	9.82	3.35	42.81	4.14
Total 150days	....	....	1553.31	98.57	190.83	337.48	858.97	67.36
Per day	....	....	10.36	.66	1.27	2.25	5.73	.45

TABLE 12.

COMPOSITION OF RATION FED.

NO. 43.

Weights in Pounds.

	Lot	Lbs. Fed	Dry Matter	Ash	Protein	Crude Fibre	Nitrogen free Extract	Ether Extract
Alfalfa Hay..	2	329.2	299.87	25.91	48.56	104.03	114.56	6.81
Grain..	D	690.0	623.21	13.31	81.03	17.31	474.47	37.24
Grain..	E	133.0	120.22	2.57	15.66	3.35	91.43	7.21
Total 130days	....	....	1043.30	41.79	145.25	124.69	680.46	51.26
Per day	....	....	8.03	.32	1.12	.96	5.23	.39

TABLE 13.

DIGESTION COEFFICIENTS OF FEEDS USED.

	Protein	Fibre	Nitrogen Free Extract	Ether Extract
Alfalfa Hay..........	72	46	69.2	51
Silage..............	49.3	66.7	68.6	80
Corn...............	67.9	....	94.6	92.1
Bran...............	77.8	28.6	69.4	68
Oilmeal.............	88.8	57	77.6	88.6
Grain Mixture A......	78.1	37.2	87.1	83.4
Grain Mixture B......	78.0	36.6	87.3	84.2
Grain Mixture C......	78.1	37.4	87.1	83.5
Grain Mixture D.	74.7	57.0	93.6	91.6
Grain Mixture E......	74.8	57.0	93.6	91.6

TABLE 14.

DIGESTIBLE NUTRIENTS IN RATIONS FED.

By average digestion coefficients.

NO. 27.

	Dry Matter	Protein	Carbo-hydrates	Ether Extract
Alfalfa Hay..........	480.86	56.07	203.86	5.57
Silage...............	635.06	20.85	357.08	21.90
Grain................	475.46	58.07	293.55	25.77
Total................	1591.38	134.99	854.49	53.24
Per day..............	9.95	.844	5.341	.333
Per day per 1000 lbs..	11.183	.949	6.005	.374

No. 62

	Dry Matter	Protein	Carbo-hydrates	Ether Extract
Alfalfa Hay..........	481.57	56.12	203.97	5.71
Silage...............	647.60	24.29	341.98	19.44
Grain................	475.67	58.05	293.70	25.76
Total................	1604.83	138.46	859.65	50.89
Per day..............	8.916	.769	4.776	.283
Per day per 1000 lbs..	9.726	.839	5.210	.309

TABLE 15.

DIGESTIBLE NUTRIENTS IN RATIONS FED.

By average digestion coefficients.

NO 63.

	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Alfalfa Hay..........	321.91	37.53	136.47	3.73
Silage...............	427.99	15.97	239.34	12.78
Grain...............	318.84	38.98	196.53	17.51
Total................	1068.74	92.49	572.34	34.02
Per day..............	8.906	.771	4.770	.283
Per day per 1000 lbs..	10.023	.868	5.368	.318

NO. 4.

	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Alfalfa Hay..........	468.20	54.59	198.49	5.43
Silage...............	621.28	20.89	349.01	20.94
Grain...............	463.73	56.72	285.78	25.48
Total................	1553.21	132.20	833.28	51.85
Per day..............	10.35	.88	5.56	.35
Per day per 1000 lbs..	13.063	1.111	7.018	.442

NO. 43.

	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Alfalfa Hay..........	299.87	34.96	127.13	3.47
Grain...............	743.43	72.24	541.46	40.62
Total................	1043.30	107.20	668.59	44.19
Per day..............	8.025	.825	5.143	.340
Per day per 1000 lbs..	10.911	1.122	6.993	.462

TABLE 16.

DRY MATTER, DIGESTIBLE PROTEIN, AND ENERGY VALUE CALCULATED FROM ARMSBY'S TABLES.

NO. 27.

	Lbs. Fed	Dry Matter	Digestible Protein	Energy Value Therms
Alfalfa Hay..........	527.9	483.56	36.58	181.65
Silage...............	2111.6	540.57	18.58	349.68
Grain...............	525.9	468.37	56.43	398.74
Total...............	....	1492.50	111.59	930.07
Per day.............	....	9.33	.70	5.81
Armsby's Standard 890 lbs..........	....	....	.46	5.55

NO 62.

	Lbs. Fed	Dry Matter	Digestible Protein	Energy Value Therms
Alfalfa Hay..........	526.4	482.18	36.48	181.13
Silage...............	2116.6	541.85	18.63	350.51
Grain...............	526.4	468.81	56.48	399.12
Total...............	....	1492.84	111.59	930.76
Per day.............	....	8.29	.62	5.17
Armsby's Standard 917 lbs..........	....	....	.47	5.66

TABLE 17.

DRY MATTER, DIGESTIBLE PROTEIN, AND ENERGY VALUE CALCULATED FROM ARMSBY'S TABLES.

NO 63.

	Lbs. Fed	Dry Matter	Digestible Protein	Energy Value Therms
Alfalfa Hay..........	353.4	323.71	24.49	121.60
Silage...............	1425.6	364.95	12.55	236.08
Grain................	353.4	314.74	37.93	267.95
Total................	....	1003.40	74.97	625.63
Per day..............	....	8.36	.62	5.21
Armsby's Standard 890 lbs............	....	....	.46	5.55

NO. 4.

	Lbs. Fed	Dry Matter	Digestible Protein	Energy Value Therms
Alfalfa Hay..........	514.0	470.82	35.62	176.87
Silage...............	2066.4	529.00	18.18	342.20
Grain................	513.9	457.68	55.14	389.64
Total................	....	1457.50	108.94	908.71
Per day..............	....	9.72	.73	6.06
Armsby's Standard 792 lbs..........	....	....	.43	5.14

NO. 43.

	Lbs. Fed	Dry Matter	Digestible Protein	Energy Value Therms
Alfalfa Hay..........	329.2	301.55	22.81	113.28
Silage..............	....	....	....	....
Grain...............	823.0	734.94	74.89	722.10
Total...............	....	1036.49	97.70	835.38
Per day.............	....	7.97	.75	6.43
Armsby's Standard 792 lbs..........	....	....	.41	4.89

TABLE 18.

NUTRIENTS DIGESTED DURING MAINTENANCE PERIOD, CALCULATED ACCORDING TO AVERAGE AND ACTUAL DIGESTIVE COEFFICIENTS.

	Protein		Crude Fibre		Nitrogen-free Extract		Ether Extract	
	Aver.	Actual	Aver.	Actual	Aver.	Actual	Aver.	Actual
No. 27.....	135.00	130.95	182.08	191.17	657.49	723.77	53.25	50.60
No. 62....	138.46	132.10	188.57	182.48	666.27	715.67	50.89	49.05
Per day No. 27....	.844	.818	1.138	1.195	4.109	4.524	.333	.316
No. 62....	.769	.734	1.048	1.014	3.702	3.976	.283	.273

SUMMARY AND CONCLUSIONS.

The maintenance requirement was determined for two cows previously used in digestion trials and for three other high class Jersey cows for periods ranging from 120 to 180 days. Four of these received the same ration except in amount as when in full flow of milk which was, corn silage 4 parts, alfalfa hay 1 part, grain mixture 1 part.

The fifth cow received the ration used at this Experiment Station for fattening steers. Complete chemical analyses were made of all food consumed. No attempt was made to determine the minimum protein requirements. The results are calculated as follows:

Constituents per day consumed, digestible nutrients using average digestion coefficients, digestible protein and energy value calculated by using Armsby's "Production Value" table, and for the two cows with which the digestion trial was made, the energy value after the plan followed by Armsby in preparing his "Production Values" table.

Armsby gives 6.00 therms energy value per 1000 pounds live weight for maintenance. The data presented shows that while there was some variation with the individuals that the four receiving the normal dairy ration averaged 6.08 therms per 1000 pounds calculated by using Armsby's "Production Value" tables.

A comparison was made with Haecker's Standard by reducing it to energy value by using Kellner's "Production Values." Calculated in this way the energy value of Haecker's ration is 8.42 therms for 1000 pounds live weight. Calculated in the same manner the average energy value required by the four cows receiving the normal ration was 8.61 therms.

The average energy value of the ration given two cows, with which a digestion trial was made that admits of more accurate calculation, was 6.00 therms while for animals of this weight the energy value required is estimated at 5.56 therms by Armsby.

The general conclusion from the results with four Jersey cows is that the average maintenance requirements of these animals is quite close to the standard, suggested by Armsby and by Haecker.

1. Farmers' Bul. 346 U. S. Dept. Agric. p. 16.

RESEARCH BULLETIN NO. 6.

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

The Distribution of Farm Labor

COLUMBIA, MISSOURI
February, 1913

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

FOREWORD

The bulletin herewith presented by O. R. Johnson is the first prepared by the Department of Farm Management. The investigational work upon which this report is based was conducted in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture. The problem here considered is one upon which there is very little definite information but is nevertheless one of importance in the economic organization of a farm business. This investigation is typical of the class of investigation which is being followed by the Farm Management Department.

F. B. MUMFORD,
Director.

CONTENTS

THE DISTRIBUTION OF FARM LABOR.

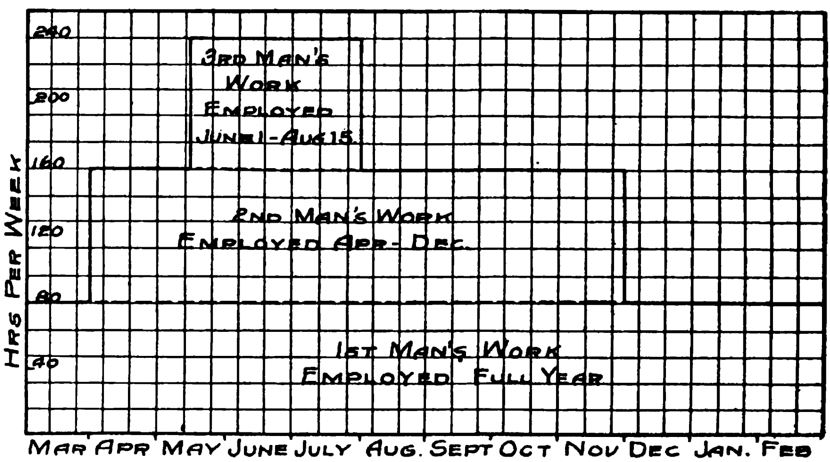
O. R. JOHNSON

Labor as a factor in farm management is of great importance. The success with which this factor is handled, determines to a great extent the success of the business. The labor phase of farming may be broadly divided into two parts: the labor equipment and the labor requirement. Labor equipment includes men and horses kept for the purpose of doing the farm work. Labor requirement includes the labor necessary to carry on farm operations. These two factors are usually intended to be equal in quantity. In other words, a farmer never intends to have more labor available than required, or vice versa. A study of labor distribution is a study of the adjustment of these factors. The problem of procuring efficient labor, commonly spoken of as the "Labor Problem" is not here considered. The adjustment of labor equipment to labor requirement of any farming system is more or less affected by special conditions. The simplest adjustment is found where the manager of the business finds it possible to employ all the labor equipment—both man and horse—for as short or as long a time as is necessary. From this simple process, the adjustment problem goes to the other extreme, where a manager must employ his help for the entire year in order to obtain help which is efficient and dependable. For the latter case the task of adjusting the two factors is most difficult. With the increasing difficulty of obtaining labor equipment goes the increasing difficulty of adjusting the two factors under any conditions. Nearly all managers have learned through long experience which farm enterprises give them the most satisfactory results under their conditions. If conditions have caused them to adopt a sytsem of farming which gives a fairly regular amount of labor through the year, this also lessens the difficulty of adjusting the two factors. Such a state of affairs however is rarely found in Missouri. The more general condition includes very irregular labor requirements together with the almost impossibility of obtaining extra, short time, labor equipment. Under ideal conditions, the meeting of this last situation will demand that the labor requirements be so influenced that regular employment, of the right kind, can be furnished the hired help during the whole period that help is hired. In the case of horse labor, the horses should be regularly employed all the time they are kept on the farm. It is inquired if some kinds of operations may not be so "very profitable" that the operator can afford to let his labor equipment be idle at some time, because of excessive profit at others. This can be answered by stating that every day labor equipment is idle in-

creases the cost of the actual labor done; that if some effort had been made to obtain employment for labor equipment during those idle days, the cost of labor on the "very profitable" operations would have been lessened by the amount of extra employment furnished, thus making the "very profitable" operations more profitable. Thus it is seen that the more regular the "production" labor, the more profitable will be the labor equipment. So it is in the interest of the men who must employ regular labor equipment, with very irregular labor requirements, that this work has been carried on. The men so situated find that, if they are to operate their farms for the year, they must hire enough man labor to do this at the opening of the crop season and keep that labor until the close, or often until the close of the calendar year. These men find it so difficult to employ extra day labor that they must make their plans in such a way that the extra help can, by putting in extra long days in the busy season, handle the work. These men usually find days when there is little to do, as well as days when each man is using every hour of daylight.

So while special conditions make special phases of the problem, there is one thing which all must face; that is, to provide regular work, of the right kind, for their helpers—no matter whether they are hired for a week, a month, or a year; if they employ one man or five at any one time, each man must have work enough to keep

FIGURE 1.—THEORETICAL CONDITION OF EMPLOYMENT FOR MAXIMUM EFFICIENCY.

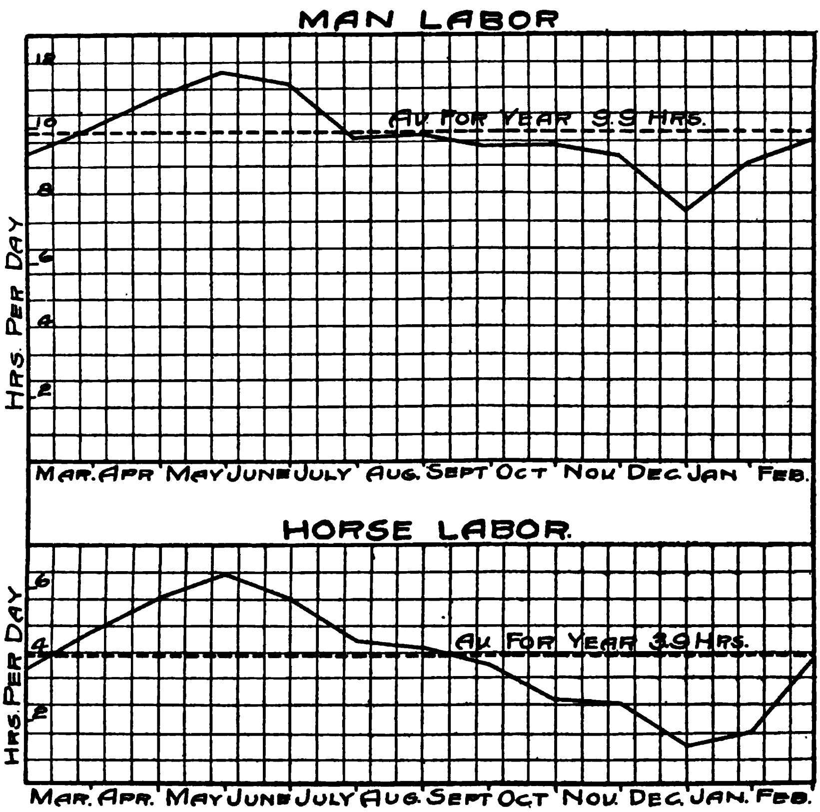


How labor would appear under ideal conditions for maximum efficiency, each workman employed working regular time per week for his period of employment.

him busy each week he works. Thus labor conditions should appear as shown in the following diagram. Each horizontal line above the base represents the total of each additional workman's labor. This line would appear horizontally if each man were kept busy every day.

This is the condition which exists in other enterprises than farming where the margin of production is very much narrower than in agriculture, so that we can see with the increase of farm efficiency will come the tendency to keep men busy regularly. For the man situated as the average Missouri farmer is situated, it has become almost a necessity that he employ a regular workman or two for at least six months and often for a year. This is in order to be sure of help when he needs it; and hiring a man for the year also enables him to get much more reliable help. In either case, the proprietor

FIGURE 2.—LENGTH OF WORK DAY.



The average length of day worked by men and horses the different months in the year is a variable quantity, emphasizing the need of effort looking toward more regular employment.

finds many times when he is not able to give his men as full days of labor as he would like. Also a part of the labor which he furnishes is not of the most productive type. The problem is to furnish regular labor and the right kind of labor.

The problem with horse labor is slightly different and a more difficult one to meet. A manager can usually hire men at some price to help in critical periods, but he finds himself compelled to own horses enough to do the work in the busy season. Consequently when the season of less demand comes he finds it impossible to employ all of his work stock. This is made very evident when we consider the variation in the length of day work per work horse on the farm, as shown by investigations carried on in Missouri by the Farm Management Department, University of Missouri, in co-operation with the Office of Farm Management, United States Department of Agriculture (See Figure 1).

The problem of the management of horse labor is a more limited one than the management of man labor. This is because the two factors in horse labor management, namely, horse equipment and available work, are but little influenced by management at the present time. The present system of diversified farming gives very little labor for the work horse outside the crop season, and when this is remembered, it is not difficult to understand why the greater part of farm work stock equipment boards with the farmer from December to April and through a part of July, August and September. Compared with this conditon, the problem of the management of man labor is a simple one to handle. Man labor equipment is easily reduced or increased as compared with horse labor equipment, and employment for men also much more easily supplied. Because of the fact that on the diversified farm about 60% of a horse's work is put in on field crops, a careful study of the crop situation will help materially in handling horse labor. And when we consider that about 70% of a man's time is devoted to miscellaneous farm labor, it must be admitted that where field labor is arranged in the best possible manner, we will still have to turn to the miscellaneous class of labor to entirely solve the problem in the handling of men. Thus both field and miscellaneous labor must be dealt with in handling this problem; and as field labor requirements are, under the best of conditions, definitely limited by those conditions, this should be provided for first in the best way possible. Then the more flexible miscellaneous labor can be moulded to fill up, as much as possible the periods of less demand during the season. In order to intelligently study any farm problem, you must first make yourself acquainted

with the actual conditions before any effort can be made to remedy those conditions. So to become familiar with the exact existing conditions with regard to farm labor, an investigation was begun in 1910, on some common types of farms to determine these conditions. Accurate record was made over a period of two years of every hour of labor put in on the farm. This labor has been classified and put in condition to study. This classification is based on the kind of labor performed, and in order to understand the classification, some explanation of the terms used will be necessary.

It will be noticed from the classification (Figure 3) that farm labor has been divided into two classes, namely up-keep, or maintenance, and production. While it is recognized that up-keep or maintenance labor is productive labor, it is separated from the other class of productive labor as indicated, that the difference between the two classes of labor may be more easily seen. The desire to distinguish between these two classes of labor arises from the fact that if a farmer should put in all his labor in maintaining or keeping up his farm and give no time to the other class of production, he would never be ahead at the end of the year's work. Maintenance labor is labor performed in maintaining the farm as a producing machine, or the keeping up of the efficiency of that machine. The farm is looked upon as a producing machine, or factory, and all work consumed in the maintaining of a certain standard of efficiency in that machine is maintenance labor. Production labor, as it is here referred to, includes all labor other than maintenance.

Under up-keep or maintenance labor, we have several divisions. The first is maintenance of equipment, or work of caring for and repairing the farm machinery. The second is maintenace of real estate, and includes repairs of buildings and fences, the prevention of washing, etc. The keeping up of the farm home, or tenant houses, in so far as they are an essential part of the farm by furnishing board for the workmen, is a part of the maintenance division. Labor in caring for and feeding work stock, because they are an essential part of farm equipment, is considered maintenance labor. Also labor chargeable to the personal account of the manager is included in the up-keep division, because such labor is a part of the price for managership.

Now to turn to production labor. The first outstanding class is crop labor, both production and marketing of crops. The other production labor includes six different classes of labor. First, we have the improving of real estate which includes clearing and draining the land, putting up new fences, buildings, water-systems, etc.

FIGURE 3.—LABOR CLASSIFICATION.

- Farm Labor
  - Production
    - Crop
      - Production
      - Marketing
    - Other
      - Improvements
      - Live Stock
        - Care
        - Feeding
        - Breeding
        - Marketing
      - New Equipment
      - Outside Labor
      - Storage ....
        - Seed ....
          - Cleaning
          - Grading
          - Marketing
        - Supplies.....
          - Meats
          - Miscl.
          - Feeds ....
            - Preparation
            - Etc.
      - Influence
  - Maintenance or Up-keep
    - Equipment
    - Real Estate....
      - Land
      - Fences
      - Buildings
    - Household
    - Work Stock
      - Care
      - Feeding
    - Personal

Then we have the care and feeding of live-stock other than work stock on the farm. This class considers work on all breeding stock, and regular daily feeding and care of all stock, except that time legitimately chargeable to work stock equipment. Here should be mentioned the distinction between work stock and brood mares used as work stock. All regular work of feeding and care of brood mares as work stock has been considered under work stock. Such work as care of a mare at foaling time, taking her to the stallion and all other attention given her that she would not receive as a work mare would be considered in the other live stock class. This account includes the production and marketing of the different classes of live-stock. This factor is either large or small, depending on the importance of live stock on the particular farm. Labor on new equipment included in this division is usually a small factor. Under this class would come only the work of purchasing, bringing home and setting up of new farm machinery. Under outside labor would fall all work done off the farm. This class is of varying importance. It can often be taken advantage of to give men and teams work in idle seasons, thus helping to solve the "keep busy" problem. It is applicable, however, to special conditions in the main. The storage factor is one that can usually be influenced by the manager of the business. The terms used are self-explanatory. A better grade of seed may be produced. It may have more attention, such as cleaning, grading and treating, thus making it more salable. Meat can often be cured on the farm and sold out to a local trade. Special care can be given fruits and vegetables to make them more valuable and provide a larger salable supply. Often extra work can profitably be given to the better preparation of feeds. Also labor performed in obtaining and maintaining good will, under the class called "influence," is included in this division. This class may be either large or small depending on conditions.

Thus we have separated for this study the labor of production from the labor of maintenance on the farm as a machine, because while the labor of maintenance must be performed, the man's profits are measured by his production labor.

In applying the classification of farm labor to find out just what conditions do obtain, the labor records collected from four Missouri farmers were used. In order to conveniently make this study an arbitrary period of time must be taken as the labor unit. Labor in this discussion is always spoken of in terms of hours, man hours and horse hours. A "man hour" is the work of one man for one hour, and by horse hour is meant the work of one horse for one hour.

Thus if a man plows ground in a certain field for four hours and uses three horses, it would be spoken of as four man hours and twelve horse hours. As the hour is a more definite period than the farm day and more convenient, it is used as the labor unit instead of the indefinite day period. In showing the proportion of labor given to the different classses of farm work, the week has been selected as the unit seasonal period. The day would be too short a period to be of value and the month would not give detail enough; as the week contains, uniformly, six work days, it is believed to be a more just and convenient unit of time. In the study of these three classes, labor will therefore be referred to in **hours per week.** The relative amount of each kind of work put in for every week covered by the record is shown. The fact should be here noted that the number of sources of data for the accompanying tables and illustrations are small, and thus the generality of conclusions will be lessened. But the value of the indications brought out are unimpaired and the usefulness of the derived tables is limited only by the small number of sources.

In all cases, any factors apart from the ordinary have been closely studied and all data that would tend to create inaccuracies, because of these extraordinary conditions, have been omitted. In other words, only regular farm enterprises have been included. For convenience of reference the different farms are numbered, and will always be referred to by their special number.

Farm No. 1 is a diversified farm of 103 acres, located in Cooper county. This is a rough farm with some bottom land. A stream runs through part of the farm and each season proves very troublesome because of washout of fences and overflowing. The effect of repairing these fences can be clearly seen in the maintenance curve at different points. This farm is equipped about as the average farm, with medium grade of work stock.

Farm No. 2 is a rolling Northeast Missouri farm in Scotland county; 160 acres, practically all tillable, are devoted to diversified farming. The land would not be considered rough. The equipment is practically all new. Two teams of mules and one team of draft mares are kept on this farm, an extraordinary quality of work stock. The greatest difficulty here from the standpoint of profit is the poor condition of the soil. This does not affect to any great extent the labor situation. In a general way, more work is expended on the crops per acre, but otherwise no influences are found beyond those which influence any labor situation.

Farm No. 3 is a level prairie farm in Boone county. It contains

160 acres of relatively low productive capacity. General farming is carried on with some attention paid to dairying. Very little equipment is kept on this farm. One of the greatest handcaps of the year's management has been lack of farm equipment. The work stock equipment compares fairly well with Farm No. 1—in other

TABLE I.—COMPARISON OF EQUIPMENT ON FARMS.

Farm	Total Acres	Acres Cultivated	Acres Per Head Work Stock	Acres Per $100 Equipment	Profit Per Acre	Type of Farming
1	103	73.7	20.6	20.00	.38	Diversified
2	160	107.9	26.6	31.35	2.82	Diversified
3	160	88.0	26.6	80.00	2.68	Div. with dairying on small scale
4	300	136.5	42.8	11.32	3.78	Dairy

TABLE II.—LABOR ON WORK STOCK AND COWS.

Showing the percent of total labor given to work stock and cows on the four farms; also the labor cost of keep per horse per day and per cow per day.

Farm	Total Labor Percent Time to work stock	Percent Time to cows	*Cost per Day per horse	*Cost per Day per cow
1	4.50	3.29	$ .038	$ .069
2	7.36	3.34	.057	.156
3	5.16	20.60	.041	.142
4	5.25	20.07	.056	.113

*Charging 15c per hour for man labor and 10c per hour for horse labor.

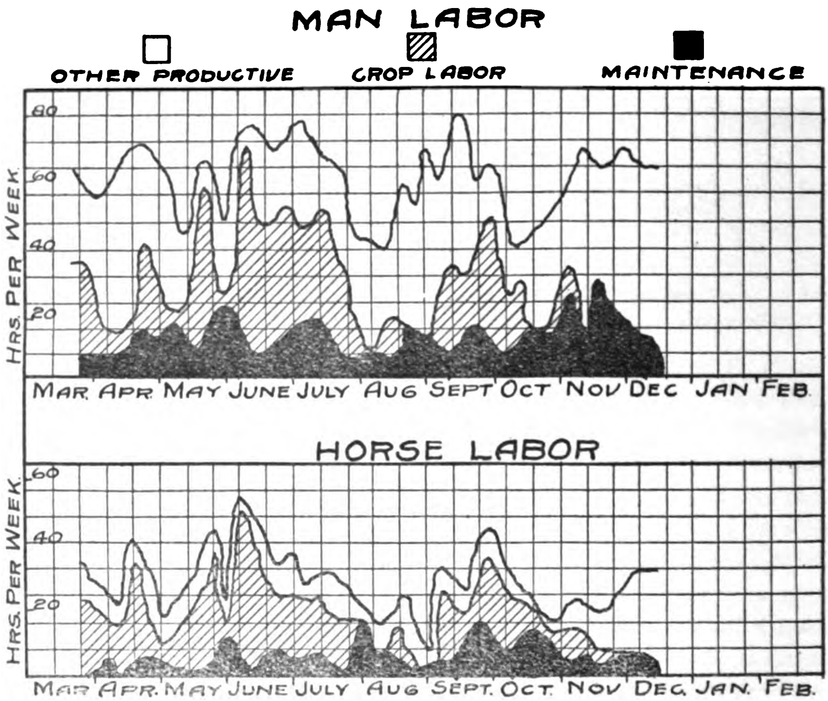
words, it would be classed as about average. With this farm, as with Farm 2, the soil has been mistreated so that more work is required than on better handled land. This factor is not a large one however. It should be said here, in justice to the operator of Farm 3, that the soil is so low in fertility that under the best of conditions it would be impossible to make any profit on most field crops. Land that will only grow 20 bushels of corn will very seldom return any profit. This farm is the only one not owned in part or wholly by the operator. A rented farm often places a good manager at a disadvantage, through the impossibility of altering or adding improvements to increase convenience and efficiency. This was especially true on Farm 3.

Farm No. 4 is a 300 acre Missouri River hill farm, located in Franklin county. It is a dairy farm primarily, and its soil is in excellent condition. This farm has more equipment than will usually be found on farms; it's work stock equipment is perhaps above the average for quality. The work is mostly done with geldings. The figures for this farm are for 1911, a dry year, and all through the season more work per acre was put in on crops than on the other

farms, but this will not affect materially the labor distribution.

In a general way, with regard to these four farms, we might say that the productive capacity of the farms would be fairly well represented by the rating of twenty bushels of corn per acre for Farm 3, thirty bushels for Farm 2, forty for Farm 1 and fifty for Farm 4. Comparison of equipment, work stock and machinery, is shown in Table I. With regard to work stock an advantage is seen in the larger farm. While more horse hours' labor were given to each acre on Farm 4, yet the number of horses kept per acre was much smaller. This is emphasized when you consider that the horses on Farm 4 worked an average of approximately 5 hours per

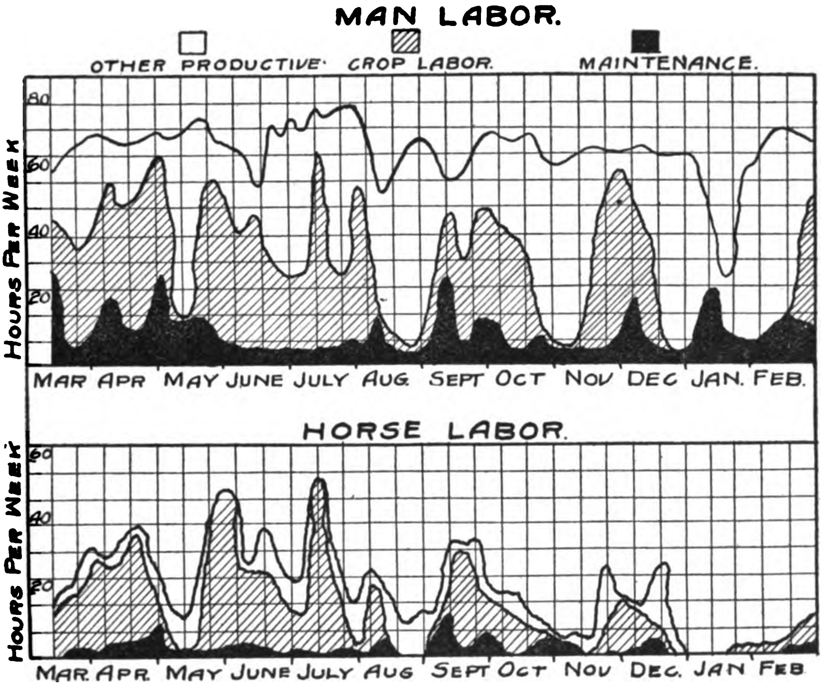
FIGURE 4.—LABOR DISTRIBUTION ON FARM 1.



Showing the distribution of labor per man and per horse each week on Farm 1. A very irregular labor arrangement which does not seem justifiable. The profits per acre were undoubtedly largely affected by this factor.

day, while the average for all the farms was 3.9 hours, or 20% less. This increase in length of day worked was not due so much to the size of farm as it was to the type of farming carried on. The investment in farm machinery in this case does not represent the re-

FIGURE 5.—LABOR DISTRIBUTION ON FARM 2.



Showing the proportion of one man's and one horse's time given to the different classes of labor each week on Farm 2. Fair regularity of the total labor curve is seen with man labor, while the horse labor curve is exceedingly irregular. While profits per acre on this farm were slightly more than on Farm 3, this could very easily have been due the better equipment and soil.

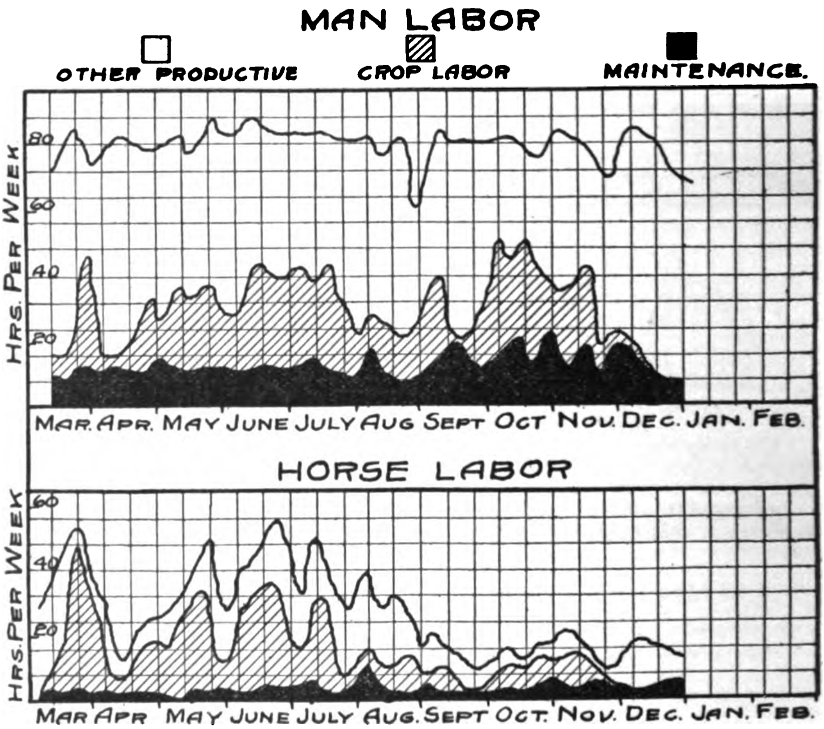
lation of investment to size of farm, but rather shows the comparative adequacy of machinery equipment.

With this brief review of the farms, a study of the curves representing the distribution of labor on these farms will prove an interesting one. The labor is figured on the one man and the one horse basis, so the different curves should be comparable.

Farm 1 shows a conspicuous absence of consistent effort to supply labor for men when they were not employed in field work. The second week in May and the end of that month, show a large decrease in labor done, due to rains. Had the work been more carefully planned, other labor would have been supplied at this time. The extreme irregularity of the maintenance labor also shows lack of system in the distribution of labor through the season. Maintenance labor can be controlled in any case to the extent that most work, except care of work stock, will come on days when other

work is scarce. This can be taken advantage of in the fall, winter or early spring, and brings up the labor curve at those times. Farm 1 shows very little effort in that direction. Regarding horse labor on this farm, great irregularity proved to be the rule. Very uneven handling of labor of maintenance together with great dependence on field work for employment is also noticed. The distribution here is a fair representation of the situation on a large number of farms.

FIGURE 6.—LABOR DISTRIBUTION ON FARM 3.



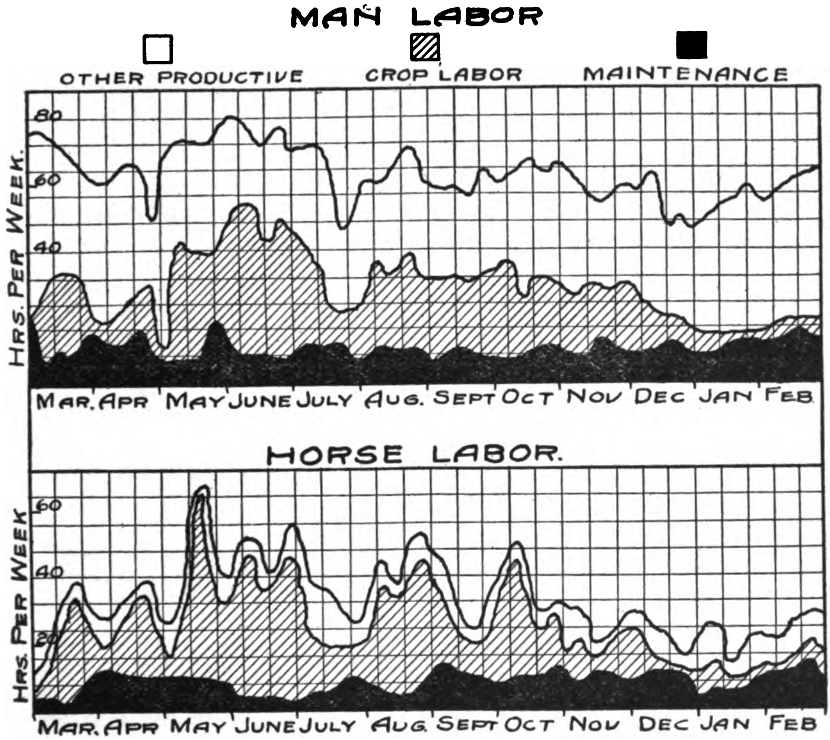
Showing the proportion of one man's or one horse's time given to the three classes of labor each week in the year on Farm 3. More regularity is seen than on any of the farms yet studied. Other production labor here aids in a remarkable way.

Plenty of work in seasons of tillage and harvest, with little in winter, late summer and early fall, is a characteristic of the more common type of farming today.

Farm 2 shows a very successful effort in providing work other than field labor, and balances up the total labor through the year fairly well. One week in January when the work was low is due to

a hard storm, which made it nearly impossible to work at all. The field work on this farm appears extremely irregular, which would

FIGURE 7.—LABOR DISTRIBUTION ON FARM 4.



Showing the proportion of one man's or one horse's time given to the three classes of labor each week in the year on Farm 4. Other production labor plays a large part in the situation. Usually on a home farm with no hired labor less effort is made to supply regular employment than on a rented farm with all hired labor. This comparison holds for Farms 3 and 4. Farm 4 succeeded in giving horses more work each week than any other farm.

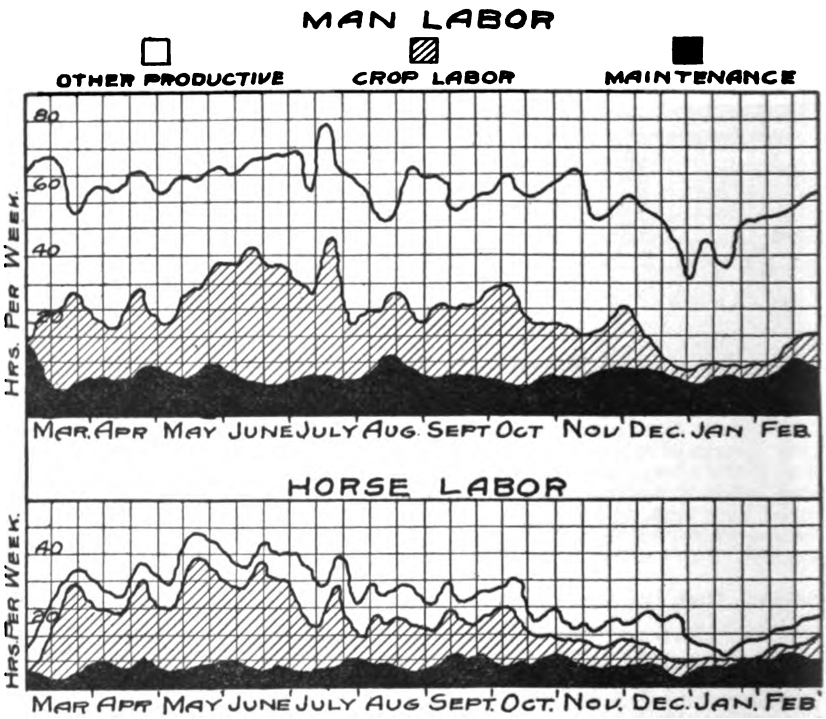
indicate that the best cropping system has not been adopted as yet. This is better understood when you consider that this farm was very dilapidated as to soil conditions and improvements. New buildings and fences were being put up at this time, thus making it easy to suppy work out of field hours. Such work can be supplied in quantity on any farm for only a limited time, but when this work is over the total labor curve will take a much different form, unless the other work of the farm is much better developed.

The situation here as regards horse labor is much less satisfactory than on the farm just studied. With a much better class

of work stock, the work was more irregular and gave very little evidence of management. It is out of the question to expect a team which does 50 hours' work for a week or two, and then runs free for the next two weeks, to remain in good condition and as able to work as one which works regularly. It will be observed here also that very little work was done outside of field labor. The first half of January the horses were not worked at all. The average length of day worked on this farm was less than on any of the others.

Farms 3 and 4 are very similar as to labor management. More success here is probably due to the dairy factor. The total labor curve on Farm 3 is more regular than that of Farm 4. The fact

FIGURE 8.—AVERAGE LABOR SITUATION OF ALL FARMS.



Showing the proportion of time of one man and one horse given to the three classes of labor each week in the year (Average of all farms).

that Farm 3 was a rented farm with nothing but hired labor, while Farm 4 was a home farm with all work done by father and sons will, in a large measure, explain such a difference. Not so marked an

effort is made to supply regular work on the home farm usually, as is the case on a farm where all hired labor is employed.

The decrease in labor on Farm 4 early in May was due to a heavy rain which almost suspended all field operations for the week. It is interesting to note that the total curve did not act entirely as the crop curve did, but recovered more quickly. The larger falling off of labor in July was due to the dry weather, the ground becoming so dry that it could not be plowed, and so field work decreased very markedly. The intense cropping system used on this farm makes field work abundant practically all season. More horse labor was furnished at all times on this farm than on Farm 3. The regularity of maintenance labor on Farm 4 is more marked than on any of the other farms.

The horse labor on Farm 3, unlike the rest, shows fairly regular other production labor. This was due largely to the delivering of milk at retail which took enough time to be noticeable. The field labor was a little more regular than on Farms 1 and 2. So also is the maintenance.

On Farm 4 appears the more regular use of horse labor in field work giving perhaps, as much regularity in this respect as will often be found. Other production labor played a fairly regular part in this labor distribution. Maintenance labor is perhaps more regularly handled here than on the other farms. As has been before mentioned, more labor was furnished for the horse equipment on this farm than on the others. The cropping system here was especially adapted to furnishing abundant horse labor. As many as three crops have been harvested from the same acre in a season. The dairy feature of this farm made such a practice possible.

From the study of the horse labor curves we see that much less regularity is shown than in the case of man labor. More regularity of employment will doubtless prove profitable in many cases.

Thus it is seen that distribution of labor on these farms is not ideal. While the dairy farms have a condition much better than the diversified farms, yet extensive improvements must be made there also. While it is possible to change cropping systems slightly, so as to give somewhat more satisfactory results, one will soon be compelled to depend on the other production labor. This is more easily understood when we consider that both other classes of labor are determined by definite factors. Take for instance maintenance labor:—on any farm there are a definite number of work stock, so many buildings and fences, so much machinery, and a certain number of acres of land to maintain. For these different definite quan-

tities so much of man's and horses' time will be required. A definite amount of time is required to care for work stock or machinery. Thus, so far as total labor goes, with maintenance, the amount is definitely fixed. Now consider crop labor. Every man has his special conditions. Under those conditions he can grow best only a few crops; and because the size of his tillable ground or work force is limited, he will grow only certain acres of each crop. Every acre of each crop grown can receive only a certain number of hours labor. Beyond this limit the increased product on that acre will not pay for the labor, so he stops there. This work can be done only at certain seasons. For instance, in a certain section wheat must be planted between September 10th and November 1st. It must be harvested in June. Such work can not be postponed to a less busy season. So that the whole field here with regard to crop labor is nearly as definitely fixed as that of maintenance labor. This will be found to be the condition of affairs in actual practice.

With this general view of the labor situation, attention is directed to its general phases. The study of special kinds of work will be divided into three classes: crop, other production and maintenance.

TABLE III.—THE PERCENTAGE OF LABOR DISTRIBUTION.

A. MAN LABOR

	Maintenance	Crop	Other Production
Farm 1	20.092	30.112	49.796
Farm 2	15.456	34.218	50.310
Farm 3	14.380	22.960	62.660
Farm 4	16.916	28.140	54.937

B. HORSE LABOR

	Maintenance	Crop	Other Production
Farm 1	21.62	51.60	26.78
Farm 2	6.83	69.48	23.69
Farm 3	6.91	51.48	41.61
Farm 4	20.17	60.10	19.73

Giving the per cent of total man and horse labor devoted to the three classes of labor on each of the four farms.

TABLE IV.—MONTHLY DISTRIBUTION OF LABOR.

	Average hours worked per month		Per cent of time given to crops		Hours given to crop production	
Month	Man	Horse	Man	Horse	Man	Horse
March	260.9	94.4	31.2	65.3	81.3	61.6
April	277.5	119.0	33.9	63.7	94.2	75.8
May	304.0	155.3	33.3	70.7	101.3	110.0
June	318.0	161.2	47.3	76.0	150.5	122.7
July	317.0	152.2	34.2	60.2	108.3	91.6
August	276.5	118.7	32.3	56.1	89.3	66.5
Sept.	271.5	106.3	31.4	58.2	85.3	61.8
Oct.	265.5	100.2	34.0	58.3	90.2	58.4
Nov.	260.7	67.5	21.5	34.8	56.0	23.5
Dec.	255.2	64.9	15.6	22.6	39.8	14.7
Jan.	225.3	35.3	7.2	19.5	16.2	6.9
Feb.	239.2	41.6	7.8	29.9	18.6	12.4
Totals	3272.3	1216.6	28.4	58.02	931.0	705.9

Giving the average number of hours that man and horse work each month; the per cent of this time devoted to field crops and the equivalent of that percent in hours; showing that men worked over 3000 hours per year and horses over 1200. 28.4% of man's time and 58% of horses' time given to field crops.

CROP LABOR.

The amount of time spent on crops shows in the case of man labor 28% and in the case of horse labor 58%. The hours given to crop work each month varied for man labor from 16 hours in January to 150 hours in June, per man;—and per horse, from 7 hours in January to 122 hours in June (Tables 3 and 4).

The study of crop and rotation requirements shown by the practices on these farms will illustrate the extent to which labor distribution can be influenced by changes of rotation. In studying the amount of labor put in on the different crops on these farms, the month was used as the unit of time. This was done because few crops are produced that must be planted or harvested in any one week. Most operations can be done a little earlier or a little later, than any special time that might be set, so that a smaller division than the month would be of no special value. It was found from the records of the four farms that the number of hours a workman works per month varies from 225 hours in January to 318 hours in June. The percent of this time devoted to field work varies from 7% in January to 47% in June. Similar figures for horse labor have also been determined. Table 4 shows how much labor one man or one horse does on field crops each month in the year.

A very careful study of these variations, and consideration of the fact that these were obtained from actual farm operations will show that such things as seasonal duty, the effect of storms and

other ordinary delays in farm work, have all been allowed for in these figures so that they represent the actual proportion of time given to crop production. The figures are not estimates, nor are they theoretical. When a man did not work for any reason, his time was not counted. If a rain kept him from the field, if he was sick, if he broke a machine and had to wait for repairs, if the hogs got into the corn field and he had to put them out, the daily record which he made showed that fact. So the figures are not based on the theory that there are 45 days in which ground can be prepared and corn planted, and that 15 of these days will be unavailable, therefore the work must be done in 30 days. Neither are they concerned with the fact that a 14-in plow going at a certain rate for a certain number of hours will turn so much ground, therefore a man will plow so much ground in a certain number of days. The work was done and the time of doing recorded without considering the theoretical results, which might be figured out on paper.

The actual labor requirements of the different farm crops have also been computed from the records of these farms (Tables 5 and 6). These figures show the man hours and horse hours per acre devoted to a particular crop that particular month. So by multiplying the acreage of a crop by the hour requirements per acre that month, one may determine the approximate amount of time which will be required for a crop in any month. This makes possible a study of the degree to which crops conflict from the standpoint of labor; also it will show when more labor will be needed and at about what time it will be needed. This enables one to plan a rotation with a minimum of conflicting operations, and to anticipate the labor requirements for the different months in the year. Such a system carefully worked out would make it possible for a man to avoid having more work than his work force at that time could do. Looking at those results briefly (Table 5 and 6) it will be found that in June, the month that the heaviest work comes with corn, clover also requires a great deal of work, thus illustrating why corn and clover do not fit well together in a rotation from a standpoint of labor requirements. Similar reasoning shows why corn and oats are a popular combination. This data may be directly useful to the man who is confronted with the problem of how much labor to hire and when he will need this labor, or how much work stock he will need to care for a certain number of acres of certain crops. These figures have been reduced to man and horse unit requirements of the common crops for the different months of the year, based on the per cent of time per man and horse given to crop

work and the hour requirements of the different crops (Tables 4 and 5). Man unit means the available time of a man for field work. Thus 1.5 man units would mean that 1.5 times what one man could give to crop work would be required. The same terms apply to horse units. The man and horse unit requirements for these crops have been worked out for acreages from 1 to 20. Assuming that these results are representative, it will then be possible to determine the number of men and horses required for different rotations each month in the year, or to determine the acreage which can best be handled by a certain amount of man and horse labor available, giving them as regular employment as possible (Tables 7 and 8).

For instance, what would be the requirements for 15 acres of corn for the month of June? Turn to Table 7 which gives the man unit requirements of crops. The first crop we come to in this table is corn. Now follow down the left hand column, which contains acres, to 15. This is the desired acreage. Now move to the right four columns. The fourth one, not counting the acres column, we find contains the number .6705. If we follow up this column, we find it to be headed June. Thus we have by reading in the June column on the same line as the required acreage, the desired man unit requirements. Similar calculation in Table 8 will give horse unit requirements. This is found to be 1.3350, or one and one-third horse's work for June. The same calculation can be made for any acreage for any month of the crops for which material has become available. In making these determinations only the normal handling of crops has been considered. The figures from these tables are taken from the four farms, and because of this fact the best that can be done in balancing up a rotation is to equal the average conditions on the four farms. It simply means that one is relying on those average conditions in using the figures in these tables. That is a safe basis for figuring. One should endeavor to do a little better than those figures indicate, however. Now to follow through a rotation and see how it fits those conditions. Take a simple cropping system of corn, oats, wheat and clover, 20 acres each, determining the labor requirements of that rotation. From the tables of man unit requirements it is found that 20 acres of corn in March requires .036 man units, oats .718 man units, with no man unit requirements for wheat or clover for this month. The total man unit requirement for this rotation for March then would be the sum of requirements for corn and oats, or .754 man units. In other words it would take about three-fourths of the time one man has to devote to crop work to care for such a rotation during

the month of March. It should be remembered that allowance has already been made for all miscellaneous labor. For horse labor units, by following the same course it is found that 2.158 horse units are required in March. The requirements for the rest of the year determined in the same way, would make the total labor requirements for the year as follows:

Month	Man Units	Horse Units
March	.754	2.158
April	.7680	2.284
May	1.400	2.846
June	1.938	3.044
July	2.582	2.076
August	1.306	1.876
September	2.012	2.508
October	1.292	3.102
November	1.214	1.932
December	1.282	2.190
January	.680	.812
February	.516	.160

Odd acreages of any crop or cropping system can be conveniently determined in the same manner. The acreages larger than 20 may be determined by adding together the units representing complements of that acreage. To illustrate: if there are 35 acres of a crop, by adding together the unit requirements for 20 acres and 15 acres, the requirements for 35 acres would be obtained. By studying the requirements for the rotation just given, it will be seen that the man unit requirements do not approach either 1, 2 or 3 man capacity very nearly in one month. In March and April, for instance, just three-fourths of the man's time will be taken, so by increasing the acreage one-fourth, or adding 5 acres to each field, a much more satisfactory labor situation is obtained with these crops. Such a change will give results as follows:

Month	Man Units	Horse Units
March	.9425	2.6975
April	.8820	2.8550
May	1.750	3.5575
June	2.4225	3.8050
July	2.8775	3.8450
August	1.6325	2.3450
September	2.5150	3.90
October	1.6150	3.8775
November	1.5124	2.4150
December	1.6025	2.7375
January	.8500	1.0150
February	.6450	.2000

This last arrangement is much better. It will be recalled from a previous diagram (Figure 1) that the best arrangement is to keep every workman regularly employed while he is on the farm.

From the above figures, it will be noticed that one man's time

is taken for the entire year, another man's time from May 1st to January 1st, and the third man is used about half time in June, July and September. For horse labor, we see 4 horses could nicely handle this rotation.

This fairly represents what will be found on many farms. It is a common rotation in this section, but the acreage in this illustration is probably better worked out than will be usually found. This is probably as convenient an arrangement as could be made with these crops on such a scale. Thus a man is able to know about **when** he needs his extra help and **how much** he needs. Many small changes can be made to add efficiency.

Clover and corn conflict very much, so if a leguminous crop can be substituted for clover to furnish a good feed, the latter may be successfully omitted from the rotation. This has been accomplished in many instances by following wheat with cowpeas. Or, as one farmer successfully handled the matter, by sowing cowpeas broadcast in corn at last cultivation; cutting the corn off in August for silage, and later cutting the cowpeas for hay. Also oats may be cut for hay in June if the July labor schedule is excessively heavy.

The many methods of harvesting corn allows a man much latitude in caring for that crop in the fall. Cowpeas and soybeans, as long as it is thought necessary to cultivate them, apparently will not fit in with corn because of the conflict in the labor schedule in planting and tending these different crops. Cowpeas sown broadcast for hay will work in much better. Thus it is seen that while actual conditions and natural limits on one farm would require that a certain crop be worked a certain way, shifts may be made in rotations which will prove beneficial to the labor schedule. But at best it will not be possible to entirely balance labor by changing the cropping system. Where regular labor is desirable, it will be found necessary to turn to the other production labor for relief.

TABLE V.—MAN LABOR REQUIREMENTS OF COMMON CROPS.

MAN HOURS PER ACRE

	Corn	Oats	Wheat	Clover
March	.15	2.92		
April	1.84	1.32		.46
May	6.38	.26		.45
June	6.72	1.11	3.2	3.56
July	2.14	3.50	6.4	.43
August	1.84	1.16	1.62	1.22
September	5.03	.17	2.70	.68
October	.78		4.2	.86
November	3.14		.26	
December	2.55			
January	.55			
February	.48			
Totals	31.60	10.44	18.38	7.66

	Rye	Timothy	Rape	Cowpeas Cult.	Cowpeas Not Cult.
April			2.3	2.1	
May					1.7
June	2.03	.48		3.3	6.6
July	2.00	6.02		4.1	
August	6.56			1.9	
Sept.	1.96				1.3
Oct.	.70			13.4	6.1
Nov.					6.3
Dec.					.78
Jan.					
Feb.					
Totals	13.25	6.50	2.3	24.8	22.78

Showing the average man hours per acre given each month to the common farm crops on four farms.

TABLE VI.—HORSE LABOR REQUIREMENTS OF CROPS.

HORSE HOURS PER ACRE.

	Corn	Oats	Wheat	Clover
March		6.65		
April	4.57	2.93		1.15
May	14.09	.79		.78
June	10.91	.87	3.2	3.38
July	3.25	3.69	6.5	.68
August	1.17	1.28	3.1	.69
September	1.73	.21	5.1	.71
October	.72		7.3	1.04
November	1.77		.5	
December	1.61			
January	.28			
February	.10			
Totals	40.20	16.42	25.7	8.43

	Rye	Timothy	Rape	Cowpeas Cult.	Cowpeas Not Cult.
April			6.4	5.9	
May					3.6
June	2.27	.63		10.7	12.0
July	2.65	9.02		5.1	
August	14.94				
Sept.	3.46				1.2
Oct.	1.27			12.6	5.1
Nov.					2.9
Dec.					.26
Jan.					
Feb.					
Totals	24.59	9.65	6.4	34.3	25.06

Showing for horse labor what Table V shows for man labor.

TABLE VII.—MAN UNIT REQUIREMENTS OF COMMON CROPS.

Giving the proportion of one man's available time required by acreages from 1 to 20 of common farm crops. Based on previously given figures.. (Tables IV and V).

	CORN												TIMOTHY	
Acres	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	June	July
1	.0018	.0195	.0630	.0447	.0198	.0206	.0590	.0086	.0561	.0641	.0340	.0258	.0032	.0555
2	.0036	.0390	.1260	.0894	.0396	.0412	.1180	.0172	.1122	.1282	.0680	.0516	.0064	.1110
3	.0054	.0585	.1890	.1341	.0594	.0618	.1770	.0258	.1683	.1923	.1020	.0774	.0096	.1665
4	.0072	.0780	.2520	.1788	.0792	.0824	.2360	.0344	.2244	.2564	.1360	.1032	.0128	.2220
5	.0090	.0975	.3150	.2235	.0990	.1030	.2950	.0430	.2805	.3205	.1700	.1290	.0160	.2775
6	.0108	.1170	.3780	.2682	.1188	.1236	.3540	.0516	.3366	.3846	.2040	.1548	.0192	.3330
7	.0126	.1365	.4410	.3129	.1386	.1442	.4130	.0602	.3927	.4487	.2380	.1806	.0224	.3885
8	.0144	.1560	.5040	.3576	.1584	.1648	.4720	.0688	.4488	.5128	.2720	.2064	.0256	.4440
9	.0162	.1755	.5670	.4023	.1782	.1854	.5310	.0774	.5049	.5769	.3060	.2322	.0288	.4995
10	.0180	.1950	.6300	.4470	.1980	.2060	.5900	.0860	.5610	.6410	.3400	.2580	.0320	.5550
11	.0198	.2145	.6930	.4917	.2178	.2266	.6490	.0946	.6171	.7051	.3740	.2838	.0352	.6105
12	.0216	.2340	.7560	.5364	.2376	.2472	.7080	.1032	.6732	.7692	.4080	.3096	.0384	.6660
13	.0234	.2535	.8190	.5811	.2574	.2678	.7670	.1118	.7293	.8333	.4420	.3354	.0416	.7215
14	.0252	.2730	.8820	.6258	.2772	.2884	.8260	.1204	.7854	.8974	.4760	.3612	.0448	.7770
15	.0270	.2925	.9450	.6705	.2970	.3090	.8850	.1290	.8415	.9615	.5100	.3870	.0480	.8325
16	.0288	.3120	1.0080	.7152	.3168	.3296	.9440	.1376	.8976	1.0256	.5440	.4128	.0512	.8880
17	.0306	.3315	1.0710	.7599	.3366	.3502	1.0030	.1462	.9537	1.0897	.5780	.4386	.0544	.9435
18	.0324	.3510	1.1340	.8046	.3564	.3708	1.0620	.1548	1.0098	1.1538	.6120	.4644	.0576	.9990
19	.0342	.3705	1.1970	.8493	.3762	.3914	1.1210	.1634	1.0659	1.2179	.6460	.4902	.0608	1.0545
20	.0360	.3900	1.2600	.8940	.3960	.4120	1.1800	.1720	1.1220	1.2820	.6800	.5160	.0640	1.1100

TABLE VII (Continued)—Man Unit Requirements of Common Crops.

	OATS							WHEAT						RAPE (Broad casted)
Acres	Mar.	Apr.	May	June	July	Aug.	Sept.	June	July	Aug.	Sept.	Oct.	Nov.	Apr.
1	.0359	.0140	.0026	.0074	.0323	.0130	.0020	.0212	.0591	.0181	.0317	.0465	.0046	.0245
2	.0718	.0280	.0052	.0148	.0646	.0260	.0040	.0424	.1182	.0362	.0634	.0930	.0092	.0490
3	.1077	.0420	.0078	.0222	.0969	.0390	.0060	.0636	.1773	.0543	.0951	.1395	.0138	.0735
4	.1436	.0560	.0104	.0296	.1292	.0520	.0080	.0848	.2364	.0724	.1268	.1860	.0184	.0980
5	.1795	.0700	.0130	.0370	.1615	.0650	.0100	.1060	.2955	.0905	.1585	.2325	.0230	.1225
6	.2154	.0840	.0156	.0444	.1938	.0780	.0120	.1272	.3546	.1086	.1902	.2790	.0276	.1470
7	.2513	.0980	.0182	.0518	.2261	.0910	.0140	.1484	.4137	.1267	.2219	.3255	.0322	.1715
8	.2872	.1120	.0208	.0592	.2584	.1040	.0160	.1696	.4728	.1448	.2536	.3720	.0368	.1960
9	.3231	.1260	.0234	.0666	.2907	.1170	.0180	.1908	.5319	.1629	.2853	.4185	.0414	.2205
10	.3590	.1400	.0260	.0740	.3230	.1300	.0200	.2120	.5910	.1810	.3170	.4650	.0460	.2450
11	.3949	.1540	.0286	.0814	.3553	.1430	.0220	.2332	.6501	.1991	.3487	.5115	.0506	.2695
12	.4308	.1680	.0312	.0888	.3876	.1560	.0240	.2544	.7092	.2172	.3804	.5580	.0552	.2940
13	.4667	.1820	.0338	.0962	.4199	.1690	.0260	.2756	.7683	.2353	.4121	.6045	.0598	.3185
14	.5026	.1960	.0364	.1036	.4522	.1820	.0280	.2968	.8274	.2534	.4438	.6510	.0644	.3430
15	.5385	.2100	.0390	.1110	.4845	.1950	.0300	.3180	.8865	.2715	.4755	.6975	.0690	.3675
16	.5744	.2240	.0416	.1184	.5168	.2080	.0320	.3392	.9456	.2896	.5072	.7440	.0736	.3920
17	.6103	.2380	.0442	.1258	.5491	.2210	.0340	.3604	1.0047	.3077	.5389	.7905	.0782	.4165
18	.6462	.2520	.0468	.1332	.5814	.2340	.0360	.3816	1.0638	.3258	.5706	.8370	.0828	.4410
19	.6821	.2660	.0494	.1406	.6137	.2470	.0380	.4028	1.1229	.3439	.6023	.8835	.0874	.4655
20	.7180	.2800	.0520	.1480	.6460	.2600	.0400	.4240	1.1820	.3620	.6340	.9300	.0920	.4900

TABLE VII (Continued)—**Man Unit Requirements of Common Crops.**

	CLOVER							RYE				
Acres	Apr	May	June	July	Aug.	Sept.	Oct.	June	July	Aug.	Sept.	Oct.
1	.0049	.0044	.0236	.0039	.0136	.0079	.0095	.0135	.0185	.0735	.0230	.0076
2	.0098	.0088	.0472	.0078	.0272	.0158	.0190	.0270	.0370	.1470	.0460	.0152
3	.0147	.0132	.0708	.0117	.0408	.0237	.0285	.0405	.0555	.2205	.0690	.0228
4	.0196	.0176	.0944	.0156	.0544	.0316	.0380	.0540	.0740	.2940	.0920	.0304
5	.0245	.0220	.1180	.0195	.0680	.0395	.0475	.0675	.0925	.3675	.1150	.0380
6	.0294	.0264	.1416	.0234	.0816	.0474	.0570	.0810	.1110	.4410	.1380	.0456
7	.0343	.0308	.1652	.0273	.0952	.0553	.0665	.0945	.1295	.5145	.1610	.0532
8	.0392	.0352	.1888	.0312	.1088	.0632	.0760	.1080	.1480	.5880	.1840	.0608
9	.0441	.0396	.2124	.0351	.1224	.0711	.0855	.1215	.1665	.6615	.2070	.0684
10	.0490	.0440	.2360	.0390	.1360	.0790	.0950	.1350	.1850	.7350	.2300	.0760
11	.0539	.0484	.2596	.0429	.1496	.0869	.1045	.1485	.2035	.8085	.2530	.0836
12	.0588	.0528	.2832	.0468	.1632	.0948	.1140	.1620	.2220	.8820	.2760	.0912
13	.0637	.0572	.3068	.0507	.1768	.1027	.1235	.1755	.2405	.9555	.2990	.0988
14	.0686	.0616	.3304	.0546	.1904	.1106	.1330	.1890	.2590	1.0290	.3220	.1064
15	.0735	.0660	.3540	.0585	.2040	.1185	.1425	.2025	.2775	1.1025	.3450	.1140
16	.0784	.0704	.3776	.0624	.2176	.1264	.1520	.2160	.2960	1.1760	.3680	.1216
17	.0833	.0748	.4012	.0663	.2312	.1343	.1615	.2295	.3145	1.2495	.3910	.1292
18	.0882	.0792	.4248	.0702	.2448	.1422	.1710	.2430	.3330	1.3230	.4140	.1368
19	.0931	.0836	.4484	.0741	.2584	.1501	.1805	.2565	.3515	1.3965	.4370	.1444
20	.0980	.0880	.4720	.0780	.2720	.1580	.1900	.2700	.3700	1.4700	.4680	.1520

TABLE VII (Continued)—Man Unit Requirements of Common Crops.

	COWPEAS (Cultivated)					COWPEAS (Not Cultivated)					
Acres	Apr	June	July	Aug.	Oct.	May	June	Sept.	Oct.	Nov.	Dec.
1	.0223	.0220	.0378	.0215	.1485	.0167	.0440	.0152	.0670	.1125	.0196
2	.0446	.0440	.0756	.0430	.2970	.0334	.0880	.0304	.1340	.2250	.0392
3	.0669	.0660	.1134	.0645	.4455	.0501	.1320	.0456	.2010	.3375	.0588
4	.0892	.0880	.1512	.0860	.5940	.0668	.1760	.0608	.2680	.4500	.0784
5	.1115	.1100	.1890	.1075	.7425	.0835	.2200	.0760	.3350	.5625	.0980
6	.1338	.1320	.2268	.1290	.8910	.1002	.2640	.0912	.4020	.6750	.1176
7	.1561	.1540	.2646	.1505	1.0395	.1169	.3080	.1064	.4690	.7875	.1372
8	.1784	.1760	.3024	.1720	1.1880	.1336	.3520	.1216	.5360	.9000	.1568
9	.2007	.1980	.3402	.1935	1.3365	.1503	.3960	.1368	.6030	1.0125	.1764
10	.2230	.2200	.3780	.2150	1.4850	.1670	.4400	.1520	.6700	1.1250	.1960
11	.2453	.2420	.4158	.2365	1.6335	.1837	.4840	.1672	.7370	1.2375	.2156
12	.2676	.2640	.4536	.2580	1.7820	.2004	.5280	.1824	.8040	1.3500	.2352
13	.2899	.2860	.4914	.2795	1.9305	.2171	.5720	.1976	.8710	1.4625	.2548
14	.3122	.3080	.5292	.3010	2.0790	.2338	.6160	.2128	.9380	1.5750	.2744
15	.3345	.3300	.5670	.3225	2.2275	.2505	.6600	.2280	1.0050	1.6875	.2940
16	.3568	.3520	.6048	.3440	2.3760	.2672	.7040	.2432	1.0720	1.8000	.3136
17	.3791	.3740	.6426	.3655	2.5245	.2839	.7480	.2584	1.1390	1.9125	.3332
18	.4014	.3960	.6804	.3870	2.6730	.3006	.7920	.2736	1.2060	2.0250	.3528
19	.4237	.4180	.7182	.4085	2.8215	.3173	.8360	.2888	1.2730	2.1375	.3724
20	**.4460**	**.4400**	**.7560**	**.4300**	**2.9700**	**.3340**	**.8800**	**.3040**	**1.3400**	**2.2500**	**.3920**

TABLE VIII.—HORSE UNIT REQUIREMENTS OF COMMON CROPS.

Giving the proportion of one horse's available time required by acres from 1 to 20 of common farm crops, based on average time given to crops and labor requirements of those crops (Tables IV and VI).

	CORN											COWPEAS (Cultivated)			
Acres	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Apr.	June	July	Oct.
1	.0603	.1280	.0890	.0354	.0176	.0280	.0123	.0753	.1095	.0406	.0080	.0778	.0873	.0556	.2160
2	.1206	.2560	.1780	.0708	.0352	.0560	.0246	.1506	.2190	.0812	.0160	.1556	.1746	.1112	.4320
3	.1809	.3840	.2670	.1062	.0528	.0840	.0369	.2259	.3285	.1218	.0240	.2334	.2619	.1668	.6480
4	.2412	.5120	.3560	.1416	.0704	.1120	.0492	.3012	.4380	.1624	.0320	.3112	.3492	.2224	.8640
5	.3015	.6400	.4450	.1770	.0880	.1400	.0615	.3765	.5475	.2030	.0400	.3890	.4365	.2780	1.0800
6	.3618	.7680	.5340	.2124	.1056	.1680	.0738	.4518	.6570	.2436	.0480	.4668	.5238	.3336	1.2960
7	.4221	.8960	.6230	.2478	.1232	.1960	.0861	.5271	.7665	.2842	.0560	.5446	.6111	.3892	1.5120
8	.4824	1.0240	.7120	.2832	.1408	.2240	.0984	.6024	.8760	.3248	.0640	.6224	.6984	.4448	1.7280
9	.5427	1.1520	.8010	.3186	.1584	.2520	.1107	.6777	.9855	.3654	.0720	.7002	.7857	.5004	1.9440
10	.6030	1.2800	.8900	.3540	.1760	.2800	.1230	.7530	1.0950	.4060	.0800	.7780	.8730	.5560	2.1600
11	.6633	1.4080	.9790	.3894	.1936	.3080	.1353	.8283	1.2045	.4466	.0880	.8558	.9603	.6116	2.3760
12	.7236	1.5360	1.0680	.4248	.2112	.3360	.1476	.9036	1.3140	.4872	.0960	.9336	1.0476	.6672	2.5920
13	.7839	1.6640	1.1570	.4602	.2288	.3640	.1599	.9789	1.4235	.5278	.1040	1.0114	1.1349	.7228	2.8080
14	.8442	1.7920	1.2460	.4956	.2464	.3920	.1722	1.0542	1.5330	.5684	.1120	1.0892	1.2222	.7784	3.0240
15	.9045	1.9200	1.3350	.5310	.2640	.4200	.1845	1.1295	1.6425	.6090	.1200	1.1670	1.3095	.8340	3.2400
16	.9648	2.0480	1.4240	.5664	.2816	.4480	.1968	1.2048	1.7520	.6496	.1280	1.2448	1.3968	.8896	3.4560
17	1.0251	2.1760	1.5130	.6018	.2992	.4760	.2091	1.2801	1.8615	.6902	.1360	1.3226	1.4841	.9452	3.6720
18	1.0854	2.3040	1.6020	.6372	.3168	.5040	.2214	1.3554	1.9710	.7308	.1440	1.4004	1.5714	1.0008	3.8880
19	1.1457	2.4320	1.6910	.6726	.3344	.5320	.2337	1.4307	2.0805	.7714	.1520	1.4782	1.6587	1.0564	4.1040
20	1.2060	2.5600	1.7800	.7080	.3520	.5600	.2460	1.5060	2.1900	.8120	.1600	1.5560	1.7460	1.1120	4.3200

TABLE VIII (Continued)— **Horse Unit Requirements of Common Crops.**

	OATS							WHEAT						RAPE (Broadcast)
Acres	Mar.	Apr.	May	June	July	Aug.	Sept.	June	July	Aug.	Sept.	Oct.	Nov.	Apr.
1	.1079	.0387	.0072	.0071	.0402	.0192	.0034	.0285	.0708	.0466	.0825	.1250	.0213	.0844
2	.2158	.0774	.0144	.0142	.0804	.0384	.0068	.0570	.1416	.0932	.1650	.2500	.0426	.1688
3	.3237	.1161	.0216	.0213	.1206	.0576	.0102	.0855	.2124	.1398	.2475	.3750	.0639	.2532
4	.4316	.1548	.0288	.0284	.1608	.0768	.0136	.1140	.2832	.1864	.3300	.5000	.0852	.3376
5	.5395	.1935	.0360	.0355	.2010	.0960	.0170	.1425	.3540	.2330	.4125	.6250	.1065	.4220
6	.6474	.2322	.0432	.0426	.2412	.1152	.0204	.1710	.4248	.2796	.4950	.7500	.1278	.5064
7	.7553	.2709	.0504	.0497	.2814	.1344	.0238	.1995	.4956	.3262	.5775	.8750	.1491	.5908
8	.8632	.3096	.0576	.0568	.3216	.1536	.0272	.2280	.5664	.3728	.6600	1.0000	.1704	.6752
9	.9711	.3483	.0648	.0639	.3618	.1728	.0306	.2565	.6372	.4194	.7425	1.1250	.1917	.7596
10	1.0790	.3870	.0720	.0710	.4020	.1920	.0340	.2850	.7080	.4660	.8250	1.2500	.2130	.8440
11	1.1869	.4257	.0792	.0781	.4422	.2112	.0374	.3135	.7788	.5126	.9075	1.3750	.2343	.9284
12	1.2948	.4644	.0864	.0852	.4824	.2304	.0408	.3420	.8496	.5592	.9900	1.5000	.2556	1.0128
13	1.4027	.0531	.0936	.0923	.5226	.2496	.0442	.3705	.9204	.6058	1.0725	1.6250	.2769	1.0972
14	1.5106	.5418	.1008	.0994	.5628	.2688	.0476	.3990	.9912	.6524	1.1550	1.7500	.2982	1.1816
15	1.6185	.5805	.1080	.1065	.6030	.2880	.0510	.4275	1.0620	.6990	1.2375	1.8750	.3195	1.2660
16	1.7264	.6192	.1152	.1136	.6432	.3072	.0544	.4560	1.1328	.7456	1.3200	2.0000	.3408	1.3504
17	1.8343	.6579	.1224	.1207	.6834	.3264	.0578	.4845	1.2036	.7922	1.4025	2.1250	.3621	1.4348
18	1.9422	.6966	.1296	.1278	.7236	.3456	.0612	.5130	1.2744	.8388	1.4850	2.2500	.3834	1.5192
19	2.0501	.7353	.1368	.1349	.7638	.3648	.0646	.5415	1.3452	.8854	1.5675	2.3750	.4047	1.6036
20	2.1580	.7740	.1440	.1420	.8040	.3840	.0680	.5700	1.4160	.9320	1.6500	2.5000	.4260	1.6880

TABLE VIII (Continued)— Horse Unit Requirements of Common Crops.

	CLOVER							RYE					TIMOTHY	
Acres	Apr.	May	June	July	Aug.	Sept.	Oct.	June	July	Aug.	Sept.	Oct.	June	July
1	.0152	.0071	.0276	.0074	.0104	.0115	.0178	.0185	.0289	.2147	.0560	.0218	.0051	.0984
2	.0304	.0142	.0552	.0148	.0208	.0230	.0356	.0370	.0578	.4294	.1120	.0436	.0102	.1968
3	.0456	.0213	.0828	.0222	.0312	.0345	.0534	.0555	.0867	.6441	.1680	.0654	.0153	.2952
4	.0608	.0284	.1104	.0296	.0416	.0460	.0712	.0740	.1156	.8588	.2240	.0872	.0204	.3936
5	.0760	.0355	.1380	.0370	.0520	.0575	.0890	.0925	.1445	1.0735	.2800	.1090	.0255	.4920
6	.0912	.0426	.1656	.0444	.0624	.0690	.1068	.1110	.1734	1.2882	.3360	.1308	.0306	.5904
7	.1064	.0497	.1932	.0518	.0728	.0805	.1246	.1295	.2023	1.5029	.3920	.1526	.0357	.6888
8	.1216	.0568	.2208	.0592	.0832	.0920	.1424	.1480	.2312	1.7176	.4480	.1744	.0408	.7872
9	.1368	.0639	.2484	.0666	.0936	.1035	.1602	.1665	.2601	1.9323	.5040	.1962	.0459	.8856
10	.1520	.0710	.2760	.0740	.1040	.1150	.1780	.1850	.2890	2.1470	.5600	.2180	.0510	.9840
11	.1672	.0781	.3036	.0814	.1144	.1265	.1958	.2035	.3179	2.3617	.6160	.2398	.0561	1.0824
12	.1824	.0852	.3312	.0888	.1248	.1380	.2136	.2220	.3468	2.5764	.6720	.2616	.0612	1.1808
13	.1976	.0923	.3588	.0962	.1352	.1495	.2314	.2405	.3757	2.7911	.7280	.2834	.0663	1.2792
14	.2128	.0994	.3864	.1036	.1456	.1610	.2492	.2590	.4046	3.0058	.7840	.3052	.0714	1.3776
15	.2280	.1065	.4140	.1110	.1560	.1725	.2670	.2775	.4335	3.2205	.8400	.3270	.0765	1.4760
16	.2432	.1136	.4416	.1184	.1664	.1840	.2848	.2960	.4624	3.4352	.8960	.3488	.0816	1.5744
17	.2584	.1207	.4692	.1258	.1768	.1955	.3026	.3145	.4913	3.6499	.9520	.3706	.0867	1.6728
18	.2736	.1278	.4968	.1332	.1872	.2070	.3204	.3330	.5202	3.8646	1.0080	.3924	.0918	1.7712
19	.2888	.1349	.5244	.1406	.1976	.2185	.3382	.3515	.5491	4.0793	1.0640	.4142	.0969	1.8696
20	.3040	.1420	.5520.	1480	.2080.	.2300	.3560	.3700	.5780	4.2940	1.1200	.4360	.1020	1.9680

TABLE VIII (Continued)
Horse Unit Requirements of Common Crops.

	COWPEAS (not cult.)					
Acres	May	June	Sept.	Oct.	Nov.	Dec.
1	.0327	.0978	.0194	.0873	.1234	.0177
2	.0654	.1956	.0388	.1746	.2468	.0354
3	.0981	.2934	.0582	.2619	.3702	.0531
4	.1308	.3912	.0776	.3492	.4936	.0708
5	.1635	.4890	.0970	.4365	.6170	.0885
6	.1962	.5868	.1164	.5238	.7404	.1062
7	.2289	.6846	.1358	.6111	.8638	.1239
8	.2616	.7824	.1552	.6984	.9872	.1416
9	.2943	.8802	.1746	.7857	1.1106	.1593
10	.3270	.9780	.1940	.8730	1.2340	.1770
11	.3597	1.0758	.2134	.9603	1.3574	.1947
12	.3924	1.1736	.2328	1.0476	1.4808	.2124
13	.4251	1.2714	.2522	1.1349	1.6042	.2301
14	.4578	1.3692	.2716	1.2222	1.7276	.2478
15	.4905	1.4670	.2910	1.3095	1.8510	.2655
16	.5232	1.5648	.3104	1.3968	1.9744	.2832
17	.5559	1.6626	.3298	1.4841	2.0978	.3009
18	.5886	1.7604	.3492	1.5714	2.2212	.3186
19	.6213	1.8582	.3686	1.6587	2.3446	.3363
20	.6540	1.9560	.3880	1.7460	2.4680	.3540

OTHER PRODUCTION LABOR.

On the farms under discussion the per cent of time given to the class of work called "other production labor" was fairly uniform with man labor, but with horses it was more irregular. (Table 3). Approximately 55% of a man's time is given to other production labor. On a strictly grain farm this class of labor is probably not so prominent; but on the diversified farm, if only to the slightest degree diversified, this class of labor plays a more or less important part.

A study of some conditions on these farms will well illustrate the importance of this class of labor. Approximately 3.3 per cent of the total labor on Farms 1 and 2 was given to cows. In this case just enough cows were kept to supply home needs. Farm 1 kept two cows at less than half the labor cost per cow that Farm 2 incurred with one cow, thus showing that a very large difference may exist in simple operations on different farms. It is these little things which help to mould final results.

When we look at Farms 3 and 4, we find 20% of the total labor devoted to cows. This shows the importance of the dairy phase of the work on these farms. This was also found to directly affect the amount of labor which it is possible to give to the work stock

each day. The delivering of milk each day played no small part in increasing the average hours per day worked by the horses. An interesting comparison may be made in the case of labor cost per cow on Farms 3 and 4 (Table 2).

The extra labor cost per cow on Farm 3 was due entirely to the difference in convenience of handling the dairy work on the two farms. Because of inadequate arrangements on Farm 3, the milking was done one-fourth mile from the house. Farm 4 was fairly well arranged for dairying. It should easily be possible to reduce the labor cost on this farm about 20%. But the extra cost of 3 cents per cow per day on Farm 3, is quite a price to pay for inconvenience, to say nothing of the profit that might have been made on this wasted labor, if it could have been used at some other phase of farm work. The excess cost would mean in a year's time, slightly over $10.00 per head, an item not to be overlooked in a business like dairying, where a man is simply changing one kind of product into another kind, and his profits are determined by the economy with which he makes the change. The margins in dairying are usually much narrower than in the growing of crops, so that $10.00 per year might make quite a good deal of difference in the profit per cow. Also $10.00 per cow would be pretty good interest on a modern dairy barn and fencing which would allow the milking to be done nearer where the milk is to be handled. Thus it will be seen that small things in the other productive labor class can, by being allowed to take their own course, lessen materially the efficiency of labor; and when the importance of the labor done on the farm outside the field is considered (Table 3) we can easily see how efficient handling of this portion of farm labor may change the results of a year's work very materially.

The breeding and feeding of other classes of live stock are important factors in the other production labor class. The production of fall pigs, winter lambs, attention given to poultry—such things will help very materially in furnishing regular work when field work is not obtainable. The hauling of manure and ferilizers in the winter months will give employment to both man and horse. Special attention to the cleaning and grading of seeds, the killing, curing and marketing of meat, more attention to the orchard and garden products in a way that will make them more salable, all such efforts will aid very materially in the successful filling in of the periods of less demand for labor. It will usually be found more difficult to handle horse labor satisfactorily.

At this point attention is called to the importance of brood

mares as work animals. The producing of both spring and fall colts will add no small item to the returns from work stock for the year. Where an abundance of warm barn space and good feed can be supplied, greater benefit in this respect will usually be received by producing fall colts. This is because the mare will not be so handicapped for work in the busy spring season as she is with a spring foal. Also she has little to do in fall and winter, so the care of a foal would keep her earning her keep. Of course fall colts would be no object to the man who has a surplus of work stock in spring, but for those who expect to keep just enough to do the work under the most difficult arrangements, such a means of using work stock in otherwise idle seasons would be a great help. Great care should be taken to select a good grade of mares as well as sure breeders. The greater cost of keeping breeding mares coupled with a somewhat less amount of work done makes readily salable products as well as regular production almost imperative. A brood mare as a work horse will usually pay for her keep in labor so that the profit realized on the foal is clear gain. In addition to this means of utilizing horse labor, another field is opening up which bids fair to aid materially a certain group of farmers.

At the present rate of development the farm tractor will probably soon be able to take the place of part of the work stock on farms of 200 acres or more, thus aiding materially in handling the labor schedule with regard to horses.

MAINTENANCE.

The maintenance factor, as has been mentioned, will under normal conditions be fairly stable. This will be a little better understood perhaps, when we mention the fact that it will take during the year about so much time to care for a definite amount of farm equipment, or of buildings and fences. As there is then a certain amount of this work to do, the best results will be obtained by arranging for all of this work that can be shifted at all, to be done at times when other work is not crowding. The work stock is one phase of this class of work that will come regularly. On the four farms this class of labor required approximately 5 per cent of the total labor of the farm (Table 3). Work of this nature must be done daily, but the repairing of machinery, buildings and fences can, to a certain extent, be shifted—if a man will plan his work ahead. This shifting will add its small part to the balancing of labor.

The different things in the foregoing study which reveal weak

places in common labor practices brings out the strong need of more study by the farmer of his individual condition in an effort to make labor a more efficient factor in his farm management. Every man should ask himself questions like the following with regard to his operations:

Is it possible for me to change my cropping system to better distribute my labor and cause fewer conflicts? Can I find some opportunity here for introducing more other production labor for men and horses out of crop season? Is my up-keep labor planned so that it is a minimum in the busy crop season?

One of the greatest aids in the bettering of the labor situation is to plan the work ahead. This planning ahead may be called making a "labor schedule." If a man can prepare before-hand a carefully made plan of the season's work, he will often be able to greatly relieve the congestion of certain seasons, and also keep his men employed at profitable labor, in what would otherwise be dull periods. The most successful farmers are those who figure ahead, and the more experience they have in this and the more detailed their plans the better they succeed. With a well planned labor schedule the manager will never send the men to cut brush along the fence rows when the binder must be overhauled for wheat cutting tomorrow, or the day after, or the granaries made ready for threshing.

When planting time begins the first day or two of good weather will not be wasted in getting seed cleaned, or getting the machinery in running order. Such a man is able to take advantage of every moment and he is the one who shows results in the end.

The problem of labor distribution or the proper adjustment of labor equipment and labor requirements is thus seen to directiy affect the profits of farm operations, and the degree to which these two factors are adjusted will directly affect, and in no small part determine, the amount of a manager's success.

SUMMARY.

1. Attention is again called to the fact that the presentation of this material is made not because it is an exhaustive treatment of methods of solving certain problems, but rather because it gives strong evidence from the limited sources at hand, of what some of these problems are. The object then is to present the problems as they have shaped themselves in the investigation up to this time and to suggest lines along which it will be possible to work in solving these problems.

2. The length of day worked varied in the case of man labor from 7.8 hours in February to 11.7 hours in June, and in the case of horse labor from 1.2 hours in January to 6.4 hours in May. The average was as follows: man 9.9 hours and horse 3.9 hours.

3. The labor required for care of work stock varied from 4½ to 7% of the total labor used on the farm. The cost of caring for horses, allowing 15 cents per hour for man and 10 cents per hour for horse labor, was from 4c to 6c per day per horse.

4. The three classes of labor on the farms studied were divided up fairly uniformly as follows: Maintenance 17%, Crop 28%, Other Production 55%. This uniformity was with man labor only. With horse labor the variation was marked. Maintenance varied from 6 to 21%, Crop 51 to 69%, and Other Production from 19 to 41%. This means that one-sixth of the work put in on the farm in these cases was given to Maintenance. In other words, no profit was realized on this portion of the labor. Effort should be made to reduce the per cent of labor given to Maintenance by increasing Other Production Labor. This would increase profits and at the same time would not decrease the amount of labor given to up-keep of the business.

5. The average workman on the farms studied worked 3272.3 hours per year, 931 hours of this time were given to Crop Production.

6. With reference to horse labor 1216.6 hours per horse were worked during the year, while 705.9 hours of this time were given to Crop Production. This illustrates the dependence of horses on crop work and the independence of man labor on this same class. The importance of making arrangements for other means of using horses than on field crops is evident. Also the arrangement of conveniences for saving time in caring for stock, etc., by the men. When 72% of a man's time is spent out of the field, the arrangement of buildings, lots, etc., may affect profits to a large extent.

7. Assuming that the crops received attention whenever they required it, the following figures give the man and horse labor requirements per acre of some common crops:

	Man Hours	Horse Hours
Corn	31.60	40.20
Oats	10.44	16.42
Wheat	18.38	25.70
Clover	7.66	8.43
Rye	13.25	24.59
Timothy	6.50	9.65
Rape	2.30	6.40
Cowpeas (cultivated)	24.80	34.30
Cowpeas (uncultivated)	22.78	25.06

8. A study of the labor requirements of crops by months gives the basis for fitting crops together from the standpoint of labor distribution.

9. A comparison of the labor requirements of crops and the number of hours available for crop work each month per man or per horse will show the men and horses required for a certain crop or the acreage of a certain rotation that a definite number of men and horses can handle.

10. Several problems are thus open for consideration. (a) An arrangement of crop rotations to give a minimum of conflicting operations is imperative. (b) More Other Production labor is essential in giving regular employment to workmen. (c) Efforts must be made to supply regular employment other than Crop Labor for farm work stock.

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COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

NUTRIENTS REQUIRED FOR MILK PRODUCTION

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October, 1913

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NUTRIENTS REQUIRED FOR MILK PRODUCTION.

C. H. ECKLES.

According to the latest census the dairy cows in the United States number nearly twenty millions. The value of the feed required each year by these animals represents an enormous sum. It is recognized that proper methods of feeding are necessary in order that this large amount of feed be used to the best advantage. This problem of economical feeding has received the attention of numerous investigators for the past fifty years.

The first attempt to assign to different feeding stuffs their true value for feeding purposes is shown in the so-called hay equivalents or hay values which were quite commonly advocated in Europe prior to the year 1860. Good meadow hay was taken as the unit and all other feeds were given relative values. These values were based upon the results of practical experiments. This method of judging the nutritive values of feeds did not prove entirely satisfactory, probably because of the limited amount of experimental work upon which it was based and because the unit for comparison, meadow hay, was too variable. A modification of this system is being used at present in some of the north European countries. Each foodstuff is given a value of a certain number of units, which represents approximately the relative nutritive values as determined by the carefully conducted feeding experiments of Fjord, a Danish investigator. These "food units" are convenient for use when buying food or when estimating the economy of production for herds or individual cows, dealing as they do entirely with the nutritive values, not the market values. Grouven[1] in 1859 is said to be the first man to suggest compounding rations with reference to the actual amounts of the different nutrients they contain—crude protein, carbohydrates, and ether extract.

Henneberg and Stohmann at Weende later showed that these constituents were not digested in the same proportions for all feeds, so it was suggested that only the digestible nutrients be used in the calculation of rations. As a result of Henneberg and Stohmann's work, Wolff, in 1864 published the first feeding standard, based upon the amount of digestible nutrients contained in feeding stuffs.

1. Exp. Station Record, v. 4, Translation from Prof. J. Kuhn.

This standard was deduced from the results of a large number of experiments at different times by different observers. It calls for 24.0 lbs. dry matter, and digestible nutrients to the extent of 2.5 lbs. protein, 12.50 lbs. carbohydrates, and .4 lbs. ether extract for a cow weighing 1000 pounds. While this seems to meet the requirements of a good average dairy cow fairly well, it is criticised for not making any allowance for a very heavy producer or a light producer.

Prof. Julius Kuhn of the Halle Experiment Station,[1] in 1861 was the first scientist of prominence to question the advisability of feeding all cows the same, irrespective of production or of kind or quality of feed. Later he proposed a standard which is somewhat more flexible than Wolff's and has the nutrients arranged a little differently. He objected to the classifying of all nitrogen compounds under the head of protein and considering them as having the same nutritive value. His standard was as follows:

Dry Matter, 20 to 23.5 lbs.
Digestible Albuminoids, 1.5 to 2.4 lbs.
Digestible Carbohydrates and Amides, 12 to 14 lbs.

While Kuhn apparently had good reasons for dividing the protein in this way, his classification did not prove popular.

In 1897, Dr. C. Lehmann of Berlin, modified the Wolff standard to meet the criticism of Kuhn and formulated what is known as the Wolff-Lehmann standard. In this the kinds and amounts of nutrients are varied with the quantity of milk produced.

WOLFF-LEHMANN STANDARD.

		Digestible Nutrients		
	Dry Matter Lbs.	Protein Lbs.	Carbohydrates Lbs.	Ether Extract Lbs.
11 lbs. milk.........	25.0	1.6	10.0	.3
16½ lbs. milk.........	27.0	2.0	11.0	.4
22 lbs. milk.........	29.0	2.5	13.0	.5
27½ lbs. milk.........	32.0	3.3	13.0	.8

This standard is probably an improvement on the original, still as Haecker has pointed out,[2] it is not clear why the nutrients

[1]loc. cit.
[2]Haecker, T. L. Bulletin 79, Minn. Exp. Station.

should not increase in the same proportion as the milk yield. For example the same amount of carbohydrates is prescribed for a cow giving 27½ pounds of milk as to the one giving 22 pounds of milk.

During the winter of 1894-5 Haecker[1] fed 12 cows a fixed ration for 154 days during which time a full flow of milk and yield of butter-fat is said to have been secured. From this record he attempted to determine whether or not the Wolff-Lehmann standard calls for an excess of nutrients. The gain in weight for this period was about 29 pounds per cow or about .2 pounds per head a day. Four of the twelve were two or three-year-old heifers. All the cows were bred during the experiment, at periods varying from 6 weeks to 4 months before its conclusion, so probably all or nearly all the cows were carrying calves. The cows were fed an average of about 12 pounds concentrates each per day along with all they would take of a mixture of timothy hay, 16 parts, and roots, 10 parts, or timothy hay, 18 parts, and silage, 14 parts. The roughage consumed amounted to about 24 pounds per head daily. The daily yield of milk was 26 pounds, testing 4.1% fat. The average weight of the cows was 956 pounds, and the digestible nutrients consumed daily were 2.00 pounds protein, 12.46 pounds carbohydrates and .67 pounds fat, or calculated on the basis of 1000 pounds live weight:

2.03 lbs. protein; 12.77 lbs. carbohydrates; .565 lbs fat.

The Wolff-Lehmann standard under similar conditions prescribes:

3.08 lbs. protein;........13.00 lbs. carbohydrates .72 lbs. fat.

It will be seen that Haecker's cows used a smaller amount of these nutrients all the way through than is provided for by the standard, the greatest difference being in the protein. Under ordinary dairy conditions in this country he is apparently justified in his assumption that the Wolff-Lehmann standard prescribes an excess of nutrients. However, if the fact be taken into account that these cows were heavily fed on concentrates and that the digestible nutrients contained therein are worth considerably more than those from roughage as has been found by Kellner and Armsby, the results lose much of their significance. His data also shows that the nutrients required for a pound of milk increase with the richness of the milk. Using this data, Haecker formulated a standard for milk of varying richness. More recently these figures have been somewhat modified in the direction of making the requirements slightly higher for milk low in fat and lower for milk rich in fat.

[1]Haecker, T. L. Bulletins 67, 79, Minn. Exp. Station.

The work of Kellner[1] and Armsby[2] shows that the plan of using digestible nutrients regardless of their source as a basis for feeding standards is inaccurate. Digestible nutrients in themselves show merely the amounts of the feed or ration which are absorbed through the walls of the alimentary tract. No allowance is made for the energy required for digestion and assimilation. Consequently those feeds which are difficult to digest, ordinarily classed as roughness, when compared with concentrates show a greater efficiency than they really possess. Armsby has found that timothy hay with 57% as much digestible material as corn meal, was worth, for flesh or fat production, only 37 % as much as the corn meal.

The question then arises: how can a feeding standard be formulated so as to represent accurately the true feeding value of the different foodstuffs? Kellner carried out extensive investigations to determine this point. He first took some of the pure nutrients such as protein, carbohydrates and fat and determined the nutritive value of each by feeding trials. These results he expressed in the form of heat value or calories. The assumption throughout is that the heat or energy value of the nutrients minus the energy required to prepare the food for use, that is to build up milk solids or body tissue, represents the true nutritive value, or production value. He found with mature fattening cattle the production values of the pure nutrients per pound to be as follows:

Digestible proteids	1016 Calories
Digestible starch or crude fibre	1071 Calories
Digestible cane sugar	812 Calories
Digestible fat:	
In coarse fodders and roots	2041 Calories
In grains and by-products	2273 Calories
In feeds with over 5% fat	2585 Calories

The next step was to apply the values so obtained to the digestible nutrients of the different feeds and compare the computed value of each feed with the real value as determined by actual feeding trials. It was found possible to estimate with a fair degree of accuracy the production value of the concentrated feeds by means of these factors. However, with those feeds containing a higher proportion of fiber this method was not reliable on account of the fact that a larger amount of energy was required for digestion. It was found that

[1]Kellner, Die Ernahrung der Landwirtschaftliches Nutztiere, Chapter IV.
[2]Armsby, Dr. H. P. Bulletins 71, 84, Pa. Exp. Station.

the energy expended in digestion was directly proportional to the amount of crude fibre present, so by deducting 617 calories for each pound of crude fibre the computed value was brought very close to the real value. This method consists then of multiplying the digestible nutrients by the caloric value of each nutrient and then making a deduction for the crude fibre.

Armsby[1] has formulated from his own and Kellner's work a system of stating the nutrients of feeding stuffs which takes the facts mentioned into account and at the same time makes it possible to express the results in a simple form. He considers that the amides, which with the albuminoids go to make up the total protein, are not as valuable as the albuminoids for nutritive purposes. He classes nutrients under two heads, those which go to form nitrogenous substances, and second, those used for heat, fat production and energy. The amount of digestible albuminoids is the measure for one and the total heat value of the nutrients used for the other. Armsby then expresses the nutritive value in two terms, digestible protein (albuminoids) and energy value. He introduces the term "therm" as a convenient term to represent 1000 calories.

He tentatively suggests, in the absence of definite experimental data, that the total energy necessary for the production of 1 pound of average milk containing 4 per cent fat and 13 percent solids, be placed at .3 therm of production value of the feed. This is in addition to that required by the animal for maintenance. Included in this ration there should be digestible amide-free protein to the extent of .05 pounds for each pound of milk. He recognizes the fact that there is necessarily a variation in the requirements with the richness of the milk but considers that sufficient data is not available to justify an attempt to formulate a standard for milk of varying richness.

Savage[2] in a recent publication compares the nutrients used by twelve cows in the Cornell University herd for periods of 142 days during two seasons with the requirements as given by Haecker and Armsby. As a result of these investigations he also suggests a modified form of Haecker's feeding standard. This increases the amount of protein by 35% and the general nutriment 10%.

[1] Armsby, Bulletin 71, Pa. Exp. Station.
[2] Savage, E. S., Bulletin 323, Cornell University Exp. Station.

PLAN OF EXPERIMENTS.

In the course of some investigations a portion of which have already been published[1], data was taken in such a way as to make it possible to study accurately the question of total nutrients required for milk production with five Jersey cows. Further plans were then made for the purpose of securing similar data taken under the same conditions but for animals producing milk with a lower per cent of fat and solids. As a result data is now available covering complete lactation periods of one year each for 8 animals with an average per cent of fat ranging from 3.4 to 6.0. In addition data is available for others taken for shorter intervals.

The taking of the data for each animal began a few days after calving. From this time on all feed received was weighed and analyzed and all the milk produced likewise sampled and subjected to chemical analysis. In this way the data obtained shows the total constituents received in the form of feed and the total production of milk and of each constituent. The ration fed was one generally used in this herd and was the same for all the animals. The amount fed each individual animal was regulated by the live weight. Each cow was given as much feed as she would take so long as it was used for milk production. If she showed a gain in live weight it was taken as an indication that more feed was being given than necessary to support the milk production.

A digestion trial covering 10 days time was made with five of the animals when they were at the maximum milk production. All the cows used in this investigation were kept farrow during the period of the experiment. A maintenance trial covering from 120 to 180 days was made with seven of the animals, in order that it might be determined specifically how much nutrients were required to maintain the particular animals. A second digestion trial was carried on while the animals were on maintenance in order to determine if the coefficient of digestibility changed when the ration is reduced from that necessary for heavy milk production to that used for maintenance. In this way it was possible to determine for each animal the actual maintenance (for 5 of the 8 cows used), the feed required for production, and the total production of milk and of each constituent of the milk.

[1]Research Bulletin No. 2, Missouri Exp. Station.

The food of the dairy cow may be used in four ways:

1. For growth or gain in weight;
2. For development of a fetus;
3. For maintenance;
4. For milk production.

The data taken in this investigation does not concern itself with Nos. 1 and 2 in the above. It is necessary, however, to either eliminate or measure these two factors. In these investigations they are both eliminated; the first by using only mature cows and regulating the ration so that they neither gained or lost in body weight; the second, by keeping the cows farrow.

Maintenance Requirement. A large amount of work has been done in regard to this factor in animal nutrition and, for cattle, the results by different investigators seem to be so consistent that it is evident that reasonable accuracy has been reached. It is not the purpose to give in detail, the data in regard to maintenance requirements for the animals used in this investigation. A portion has already been published[1] and only a summary will be given of this and the remainder, which as yet is not published. It is sufficient to say that the results on the whole compare closely with the standard as published by Armsby.[2] It was considered advisable in making our experiments to determine the maintenance requirements for each animal individually so far as practical rather than to use average figures. Furthermore, the maintenance trials were conducted with exactly the same ration, including the ratio between the grain and roughage, as used when the animals were fed for milk production. In this way it is possible to estimate the proportion of the ration fed to the cows while in milk that was necessary for maintaining the animal.

Requirements for Milk Production. The object in carrying out the investigation here reported was to obtain further data in regard to the amount of nutrients required for milk production when other factors for which food may be used are controlled. The special object in view was to so select the cows used that it would be possible to secure data bearing on the question of the relation of the richness of the milk to the amount of nutrients needed. The figures below show the average value in therms per pound of milk produced by each of the 10 cows used in the investigation.

[1]Research Bulletin No. 5, Missouri Exp. Station.
[2]Armsby, Farmers' Bulletin 346, U. S. Dept. Agr.

Cow No.	Therms
206	.276
304	.304
400	.313
43	.352
62	.383
4	.388
27	.392
63	.420
303	.307
211	.273

These figures show that the milk of No. 63 had an energy value of a little over 50% more per lb. than that of No. 206. It is reasonable to assume that the nutrients required per pound of milk will therefore depend upon the quality as well as the quantity of the milk. The nutrients received by the animal must supply protein and furnish sufficient energy in the form of carbohydrates and fats.

Protein Requirements. It was not the purpose of this investigation to study the amount of protein best adapted to the production of milk. The protein requirement is discussed here merely to show, first, that moderate variations in the protein content of a ration have no marked influence upon milk production provided the allowance is above the minimum requirement of the animals, and, second, that the rations used in this investigation contained protein sufficient for all purposes for which it is intended. The Wolff-Lehmann standard prescribes 1.6 lbs. to 3.3 lbs. digestible protein for a 1000-lb. cow yielding 11 to 27½ lbs. milk per day. Haecker has demonstrated by feeding 12 cows for 154 days on two-thirds the amount of protein prescribed by this standard that it is possible for milk production to proceed with considerable less than the amount given in the standard referred to. Humphrey and Woll[1] suggest that the digestible protein may profitably range from 2 lbs. to 2.4 lbs. per day. According to Haecker [2]a cow weighing 850 lbs. and yielding 40 lbs. of 4% milk per day required 2.46 lbs. digestible protein. A 1200-lb. cow producing the same amount requires 2.71 lbs; while an 850-lb. cow producing 20 lbs. per day would use but 1.52 lbs. The ration which was used in the investigations reported supplied as much protein as was required by any of these standards as is shown in detail in a later paragraph.

[1]Humphrey and Woll, 21st Annual Report, Wis. Exp. Station (1904), p. 67.
[2]Haecker, T. L. Bulletin 79, Minn. Exp. Station.

Animals Used. The animals used were all registered animals of the breeds represented and were not especially selected on account of large production. It has already been shown by work of this Station that when the richness of the milk is the same the nutrients required for production after maintenance has been supplied are in the same proportion as the production of the animals.[1] All the cows selected were of mature age, healthy, and at the beginning of the milking period. Data concerning the age and previous milk production of each cow is given below:

DATA CONCERNING COWS USED.

Herd No.	Breed	Age		Number lactation periods	Average yield Milk	Average per cent fat	Average yield fat
		Yrs.	Mo.				
206	Holstein	8	6	6	9,763	3.15	308
304	Ayrshire	4	6	3	6,582	3.96	261
400	Shorthorn	7	8	4	4,694	4.20	197
43	Jersey	5	1	3	6,812	4.82	329
62	Jersey	4	6	4	2,503	4.86	122
4	Jersey	7	4	5	6,151	5.04	310
27	Jersey	5	1	5	7,810	5.31	415
63	Jersey	4	7	3	4,909	5.86	288
303	Ayrshire	4	7	3	6,843	3.98	273
211	Holstein	7	0	4	12,665	3.06	388

The two given last in the table are those for which the data presented covers less than one year.

Ration Used. The cows all received the same character of ration, i. e., it was composed of the same kind and quantity of feeds mixed in the same proportions. The ratio between the silage and hay was kept as nearly uniform as possible. The roughage consisted of alfalfa hay of the grade known as "choice" and corn silage. For the first five animals put into the experiment green feed was substituted for the silage during the summer months. The last three had only alfalfa for roughness during the middle of the summer. These changes were necessary on account of it not being feasible to keep silage in condition for feeding with the few animals used.

The grain ration consisted of a mixture composed of corn meal, 4 parts, wheat bran, 2 parts, and linseed oil meal, 1 part. This grain mixture was fed in exactly this proportion to all the animals throughout the entire investigation including the maintenance trials. The feeds were fed as nearly as possible in the following proportion: grain, 1 part; hay, 1 part, and silage, 4 parts. The follow-

[1]Research Bulletin No. 2, Missouri Exp. Station.

ing table shows how closely this ration, fed in the proportions mentioned, will meet the requirements of both a heavy and light producing cow computed according to Armsby[1]. The weight of the cow is taken as 1250 pounds, the per cent of fat as 4, and the daily yield of milk as 40 pounds in the first instance and 15 pounds in the second.

	Digestible Protein	Therms
Required for 40 lbs. milk..........	2.6	19.00
Supplied in 11 lbs. grain, 11 lbs. hay, 44 lbs. silage.................	2.5	19.35
Required for 15 lbs. milk..........	1.35	11.50
Supplied in 6.5 lbs. grain 6.5 lbs. hay, 26 lbs. silage......	1.47	11.44

With our present knowledge of the protein requirements for milk production there can be no serious objection to the above ration on this score. The quantity of feed given was regulated as stated by the live weight of the animal. The cows were fed as much as was required to support the milk flow without allowing gain or loss in body weight.

All the cows were fed and milked in the same way as far as the routine of the work was concerned. They were not all in the experiment at the same time and the milking was therefore done by different men. Careful observations were made and notes taken regarding the health of the cows, their feeding characteristics, and any conditions or happenings out of the ordinary.

Analyses of Feed. The feed was purchased in sufficient quantities to make the number of analyses as small as feasible. The silage was sampled by taking a small quantity each day from that fed and placing it in a large closed jar in which sufficient chloroform was kept to prevent decomposition. The moisture in this composite sample was determined at the end of each 10-day period. A sample for complete analysis was made by combining the dry material from several of the 10-day samples. All feed analyses were made in the Department of Agricultural Chemistry under the direction of Dr. P. F. Trowbridge.

Sampling and Analyzing the Milk. The milk was weighed at the barn immediately after being drawn and the weights recorded upon the regular milk sheets. The milker then stirred the milk with a dipper and filled a pint milk jar about two-thirds full. This

[1]Armsby, Dr. H. P., Farmers' Bulletin 346, U. S. Dept. Agr.

was covered with a paper cap and taken to the laboratory where a 10-day composite sample was prepared by taking an aliquot part from each milking. With cows Nos. 63, 4 and 43 the composite sample covered thirty days in place of ten days. Formalin was used as a preservative and the chemical analyses which were made according to usual methods included fat, protein, sugar and ash.

Weights of cows. Each cow was weighed each morning after eating and before receiving water. This practice was continued during the entire period of milk production and maintenance and has been found to be the most satisfactory plan. The heaviest milkers lost some weight at the beginning of the feeding period as is the case with all heavy producing cows in the first few weeks after calving. This loss was restored during the year so the cows completed the experimental period as nearly as possible at the same weight as at the beginning.

EXPERIMENTAL DATA.

Tables 1 to 8 give a record by 10-day periods of the feed received by eight of the cows used during the time in milk. The same data for cows Nos. 27 and 62 have already been published.[1]

Table 9 gives the total of each feed received by the individual cows, also their average weight during the period in milk covered by the experiment.

The chemical analyses of the feedstuffs given are found in Tables 10 and 11. The five Jersey cows were on experiment at one time and the other five at a later date which accounts for the two series of analyses.

Tables 12 and 13 give the amount in pounds of each feedstuff according to lot numbers corresponding to analyses. From this date it is possible to calculate the data in other forms than the one presented if desirable. This data concerning the feed covers only that received by the cows while in milk and does not cover that given during the maintenance trials.

The milk yields together with chemical analyses for each period are found in Tables 14 to 21. This includes the date in detail for eight animals. The same records for Nos. 27 and 62 are already available in printed form.[2] The date for Nos. 63, 4 and 43 is given in 30-day periods to correspond to the milk analyses, and that of all others for 10-day periods. All averages relating to milk analyses

[1]Research Bulletin No. 2, Missouri Exp. Station (Tables 4 and 5).
[2]Research Bulletin No. 2, Missouri Exp. Station (Tables 8 and 9).

throughout this report are true averages calculated by dividing the total weight of the constituent by the total pounds of milk.

Table 22 gives the total yield of each constituent of the milk and the average analyses. In Table 23 is found the energy value of the total milk and per pound of milk calculated by assuming the heat value of milk protein and sugar to be 1.860 therms and fat 4.218 therms per pound.[1]

TABLE 1. SUMMARY OF FEED CONSUMED BY COW NO. 206.

Period No.	Date 10 days ending	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Average weight o cow Lbs.
1910					
1	Dec. 1*	59	59	233	1292
2	Dec. 11	116	116	464	1295
3	Dec. 21	120	116	261	1286
4	Dec. 31	120	120	394	1286
1911					
5	Jan. 10	120	116.5	386	1284
6	Jan. 20	100	94.5	312.5	1236
7	Jan. 30	110	110	400	1292
8	Feb. 9	110	110	400	1330
9	Feb. 19	110	110	400	1324
10	Mar. 1	110	110	400	1311
11	Mar. 11	110	110	400	1340
12	Mar. 21	110	110	400	1352
13	Mar. 31	101	101	400	1349
14	Apr. 10	100	100	400	1340
15	Apr. 20	92	100	400	1364
16	Apr. 30	90	90	400	1367
17	May 10	80	83	400	1354
18	May 20	80	80	400	1344
19	May 30	80	80	369	1345
20	June 9	89	241.5	....	1356
21	June 19	90	250	....	1341
22	June 29	90	250	....	1348
23	July 9	73	213	....	1339
24	July 19	80.5	221	....	1304
25	July 29	85	227.9	....	1302
26	Aug. 8	85	228	....	1301
27	Aug. 18	80.5	222	....	1306
28	Aug. 28	85	230	....	1299
29	Sept. 7	85	230	....	1298
30	Sept. 17	85	230	....	1322
31	Sept. 27	85	230	....	1329
32	Oct. 7	80	230	....	1319
33	Oct. 17	73.6	214	....	1325
34	Oct. 27	70.4	210	....	1313
35	Nov. 6	70	177	44	1313
36	Nov. 16	70	95	203	1284
37	Nov. 26	70	70	280	1299
Total		3365.0	5685.4	7946.5	Av. 1319

* 5 Days.

[1]Armsby, Principles of Animal Nutrition, p. 279.

TABLE 2. SUMMARY OF FEED CONSUMED BY COW NO. 304.

Period	Date 10 days ending	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Average weight of cow Lbs.
1911					
1	Jan. 20	99	95.5	304	976
2	Jan. 30	105	97	305	973
3	Feb. 9	120	90	294	995
4	Feb. 19	100	85	300	972
5	Mar. 1	97.5	90	265	973
6	Mar. 11	82	90	257	959
7	Mar. 21	100	90	300	965
8	Mar. 31	100	90	300	962
9	Apr. 10	76	75.5	259	963
10	Apr. 20	69	69	283	953
11	Apr. 30	70	70	300	967
12	May 10	66.5	69	276	956
13	May 20	70	70	300	965
14	May 30	70	70	282	954
15	June 9	79	193.5	....	982
16	June 19	80	200	....	984
17	June 29	80	200	....	974
18	July 9	76	194	....	982
19	July 19	70.5	184	....	950
20	July 29	75	200	....	972
21	Aug. 8	78	206	....	962
22	Aug. 18	85	215.2	....	990
23	Aug. 28	85	218	....	969
24	Sept. 7	85	220	....	982
25	Sept. 17	68	201	....	975
26	Sept. 27	85	220	....	987
27	Oct. 7	80	220	....	983
28	Oct. 17	75.2	206	....	993
29	Oct. 27	70.8	200	....	985
30	Nov. 6	69	167	44	1006
31	Nov. 16	60	88	189	982
32	Nov. 26	60	60	240	981
33	Dec. 6	60	60	240	991
34	Dec. 16	58.5	58.5	234	1005
35	Dec. 26	55	55	220	982
1912					
36	Jan. 5	58.5	58.5	234	970
37	Jan. 10*	31	31	124	975
Total		2849.0	4806.7	5550	Av. 976

* 5 Days.

TABLE 3. SUMMARY OF FEED CONSUMED BY COW No. 400.

Period	Date 10 days ending	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Average weight of cow Lbs.
1910					
1	Dec. 31*	35	35	140	1134
1911					
2	Jan. 10	70	70	329	1111
3	Jan. 20	79	79	350	1120
4	Jan. 30	80	80	350	1144
5	Feb. 9	80	80	350	1150
6	Feb. 19	80	80	350	1151
7	Mar. 1	80	80	350	1162
8	Mar. 11	71	71	350	1173
9	Mar. 21	70	70	350	1170
10	Mar. 31	61	61	350	1168
11	Apr. 10	60	60	350	1174
12	Apr. 20	44	60	350	1180
13	Apr. 30	50	50	300	1154
14	May 10	50	50	300	1168
15	May 20	50	50	300	1145
16	May 30	50	50	301	1139
17	June 9	59	173.5	....	1167
18	June 19	60	180	....	1162
19	June 29	60	180	....	1153
20	July 9	59	180	....	1154
21	July 19	50	180	....	1137
22	July 29	50	180	....	1144
23	Aug. 8	50	180	....	1131
24	Aug. 18	50	177.5	....	1130
25	Aug. 28	50	179	....	1131
26	Sept. 7	50	180	....	1135
27	Sept. 17	50	180	....	1125
28	Sept. 27	50	180	....	1127
29	Oct. 7	50	164	....	1129
30	Oct. 17	40	164	....	1139
31	Oct. 27	36	160.8	....	1134
32	Nov. 6	35	136	44	1142
33	Nov. 16	35	72	132	1131
34	Nov. 26	35	35	140	1130
35	Dec. 6	35	35	140	1150
36	Dec. 16	35	35	140	1135
37	Dec. 26	46.1	46.1	184.4	1113
Total		1995.1	4023.9	5950.4	Av. 1144

* 5 Days.

TABLE 4. SUMMARY OF FEED CONSUMED BY COW NO. 43 BY 10-DAY PERIODS.

Period	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Green feed Lbs.	Average weight Lbs.
1	12	40		....	825
2	91	200	....	....	....
3	120	90	300	....	....
4	120	90	300	....	....
5	120	90	300	....	795
6	120	90	235	....	790
7	114	90	230	....	810
8	110	90	250	....	809
9	106	90	270	....	816
10	100	90	270	....	810
11	103	90	270	....	812
12	100	92	259	....	793
13	100	100	277.5	....	819
14	100	100	211.5	....	805
15	100	100	221	....	799
16	100	100	250	....	806
17	100	100	231	....	799
18	103	103	196	....	793
19	110	110	200	....	791.5
20	109	110	168	....	801.5
21	100	110	185.5	....	803
22	98	108	192.5	12	807
23	93	76	145.8	144	796
24	90	78	129.5	234	779.5
25	90	108	99.5	15	777
26	90	88	150	40	793
27	81	80	131.2	122.7	793.5
28	80	80	141.2	133.6	789.5
29	80	80	138.9	122.6	815.0
30	80	80	68.2	187.5	811.5
31	80	98	....	219.1	812
32	80	100	....	223.0	808
33	80	100	....	250	809.5
34	80	100	....	250	820.4
35	80	100	....	250	823.7
36	68	100	....	247.4	838
37	50	100	70.4	....	843.5
38	16	40	94.9	....	840
Total	3454	3591	5986.5	2450.9	Av. 807

TABLE 5. SUMMARY OF FEED CONSUMED BY COW NO. 4 BY 10-DAY PERIODS.

Period	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Green feed Lbs.	Average weight Lbs.
1	92	129	....	....	....
2	98	147	....	....	....
3	100	114	180	....	805
4	100	90	300	....	800
5	100	90	300	....	815
6	100	90	300	....	817
7	100	90	300	....	815
8	100	90	300	....	821
9	100	90	300	....	816
10	100	90	300	....	813
11	100	90	294.5	....	814
12	100	90	300	....	807
13	100	90	300	....	819
14	100	90	300	....	813
15	100	90	300	....	818
16	100	90	300	....	820
17	100	100	300	....	815.5
18	100	100	285	....	810
19	76	78	112	....	804.5
20	90	92	262.5	12	807.5
21	90	66	213.5	144	810.5
22	90	64	180	216	808
23	90	105	160.5	12	800.7
24	90	88	175.3	30	808
25	81	74	187	134.5	822
26	71	80	234.2	145	839
27	70	80	217.2	128	859
28	65	80	114.8	190.8	855
29	65	98	....	235.2	841
30	65	100	....	242.6	843
31	65	100	....	250	836.5
32	65	100	....	250	832.5
33	65	100	....	250	851
34	49.8	100	....	250	852.5
35	36.5	100	250	....	860.5
36	21	100	250	....	865.5
37	....	60	63	....	849.5
Total	3035.3	3425	7078.8	2490.1	Av. 825

TABLE 6. SUMMARY OF FEED CONSUMED BY COW NO. 63 BY 10-DAY PERIODS.

Period	Grain Lbs.	Alfalfa Lbs.	Silage Lbs.	Green feed Lbs.	Average weight Lbs.
1	23	60	....	....	960
2	120	90	300	....	....
3	120	90	300	....	....
4	106	90	300	....	930
5	100	90	300	....	910
6	100	90	300	....	945
7	1000	90	300	....	941
8	100	90	300	....	942
9	100	90	300	....	941
10	100	90	300	....	951
11	91	90	300	....	939
12	90	90	300	....	946
13	90	90	300	....	935
14	90	90	300	....	939
15	90	90	300	....	941
16	90	90	300	....	942
17	90	90	300	....	935
18	90	90	300	....	947.4
19	90	90	300	....	950.7
20	87	90	300	....	956
21	80	86	294	12	951.5
22	80	56	216.3	144	933.5
23	80	54	180	234	919
24	80	104	156.5	15	914
25	80	80	193.5	40	936
26	80	80	206.5	137.5	941
27	80	80	207.1	145	942.5
28	80	80	228.6	126	962.0
29	68.5	80	89.6	190.1	968
30	50	98	....	232.1	947.5
31	80	100	....	225.6	951
32	80	100	....	250	951.5
33	80	100	....	250	962.5
34	54.5	100	....	250	977.2
35	18	100	....	250	973
36	....	100	249.6	....	972.5
37	21	100	250	....	967
38	9	30	75	....	952
Total	2968	3298	8046.7	2501.3	Av. 952

TABLE 7. SUMMARY OF FEED CONSUMED BY COW NO. 303 BY 10-DAY PERIODS.

Period No.	Date 10 days ending	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Average weight of cow Lbs.
1911					
1	Jan. 30	80	80	294	991
2	Feb. 9	96	96	300	1010
3	Feb. 19	100	93.5	280	1004
4	Mar. 1	91	89	295	1003
5	Mar. 11	90	90	300	1028
6	Mar. 21	90	90	300	1023
7	Mar. 31	81	81	300	1039
8	Apr. 10	70	70	300	1029
9	Apr. 20	54	70	340	1047
10	Apr. 30	60	60	300	1039
11	May 10	50	50	300	1024
12	May 20	50	50	300	1002
Total		912	919.5	3609	Av. 1020

TABLE 8. SUMMARY OF FEED CONSUMED BY COW NO. 211 BY 10-DAY PERIODS.

Period No.	Date 10 days ending	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Average weight of cow Lbs.
1911					
1	Dec. 6	100	100	400	1052
2	Dec. 16	100	100	400	1075
3	Dec. 26	101.5	101.5	406	1039
1912					
4	Jan. 5	109	109	436	1035
5	Jan. 15	110	110	440	1045
6	Jan. 25	115	115	460	1060
7	Feb. 4	113.5	113.5	464	1067
8	Feb. 14	110	110	440	1069
9	Feb. 24	108.5	108.5	434	1065
10	Mar. 5	106	106	424	1063
11	Mar. 15	105	105	420	1048
Total		1178.5	1178.5	4714.0	Av. 1056

TABLE 9. SUMMARY OF FEED CONSUMED.

Cow No.	Days	Grain Lbs.	Alfalfa hay Lbs.	Silage Lbs.	Green feed Lbs.	Average weight Lbs.
206	365	3365.0	5685.4	7946.5	....	1319
304	365	2849.0	4806.7	5550.0	....	976
400	365	1995.1	4023.9	5950.4	....	1144
43	365	3454.0	3591.0	5986.5	2450.9	807
62	365	1907.3	1697.8	5087.5	2101.9	902
4	365	3035.3	3425.0	7078.8	2490.1	825
27	365	3424.0	2904.1	8777.9	4325.2	899
63	365	2968.0	3298.0	8046.7	2501.3	952
303	120	912.0	919.5	3609.0	....	1020
211	110	1178.5	1178.5	4714.0	....	1056

TABLE 10. CHEMICAL ANALYSES OF FEEDS FED NOS. 27, 62, 43, 4 and 63.

	Lot	Per cent Dry matter	Per cent Ash	Per cent Protein	Per cent Crude fibre	Per cent N. free extract	Per Cent Ether extract
Corn	1	85.04	1.19	7.97	1.90	69.99	3.99
	2	87.89	1.29	8.68	1.67	68.53	7.73
	3	90.25	1.50	8.91	1.81	72.80	5.23
Bran	1	89.51	6.67	14.55	8.49	55.06	4.75
	2	89.82	6.75	14.44	9.19	52.46	6.98
Oilmeal	1	90.89	5.36	34.36	7.98	36.45	6.74
Oats	1	89.60	3.20	11.40	10.80	59.40	4.80
Alfalfa hay	1	94.69	7.73	15.24	27.97	41.95	1.80
	2	94.16	8.25	12.69	36.35	35.33	1.56
	3	95.27	9.93	14.13	27.68	39.92	3.61
	4	94.23	8.88	15.48	28.71	37.97	3.19
	5	95.06	9.03	16.39	28.72	38.20	2.72
	6	91.09	7.87	14.75	31.60	34.80	2.07
Silage	1	20.58	1.40	1.68	5.80	11.02	69
	2	29.29	1.81	1.99	7.08	17.58	.83
	3	31.22	1.51	2.26	6.17	19.79	1.48
	4	27.56	1.69	2.41	5.14	17.28	1.04
	5	29.63	2.05	2.10	7.09	17.57	.83
	6	29.99	1.97	2.43	7.45	17.13	1.02
Green Alfalfa	1	24.54	2.63	4.63	7.27	9.60	.41
Green Clover	1	38.79	2.50	5.29	11.03	19.12	.85
Green Corn	1	27.72	1.88	2.32	7.09	15.49	.94

TABLE 11. CHEMICAL ANALYSES OF FEEDS FED NO. 206, 400, 304, 303 and 211.

	Lot	Per cent Dry matter	Per cent Ash	Per cent Protein	Per cent Crude fibre	Per cent N. free extract	Per cent Ether extract
Corn	1	88.20	1.52	8.56	1.71	71.64	4.77
	2	87.80	1.20	8.12	2.30	72.52	3.67
	3	89.62	1.48	9.26	1.63	72.17	5.08
	4	90.04	2.40	9.33	1.88	73.68	2.76
Bran	1	90.26	7.18	15.61	10.46	51.09	5.92
	2	89.10	6.61	15.43	9.17	54.64	3.26
	3	88.42	6.93	13.98	9.70	53.97	3.85
	4	89.29	6.40	16.73	9.80	51.20	5.16
Oilmeal	1	91.49	6.26	36.40	7.98	35.34	5.51
	2	90.86	5.68	35.79	8.01	36.84	4.54
	3	90.47	6.07	34.38	7.90	35.51	6.61
	4	90.34	5.76	31.46	7.57	35.65	9.91
Alfalfa	1	90.72	8.95	14.33	28.56	35.96	2.92
	2	91.11	9.08	15.72	24.89	37.56	3.86
	3	90.78	10.06	17.09	23.49	36.47	3.67
	4	92.35	9.16	17.93	22.80	39.38	3.09
	5	91.95	6.89	14.71	27.65	40.74	1.97
	6	89.25	7.78	13.08	26.90	38.47	3.03
Silage	1	32.90	1.97	2.53	8.09	19.84	.48
	2	30.01	1.59	2.31	7.05	18.58	.47
	3	33.46	1.85	2.54	7.30	20.17	1.60
	4	32.95	2.51	2.54	7.20	19.84	.86
	5	31.86	3.88	4.41	7.48	14.38	1.71
	6	27.09	1.76	2.60	5.66	16.54	.32

TABLE 12. AMOUNT OF FEED BY LOTS RECEIVED BY COWS NOS. 27, 62, 43, 4 and 63. (Pounds)

	Lot	No. 43	No. 62	No. 4	No. 27	No. 63
Corn	1	814.8	453.1	745.1	661.1	714.7
	2	102.8	65.3	102.8	113.1	92.6
	3	1056.0	554.3	945.8	1165.1	889.7
Bran	1	436.0	264.4	323.1	382.0	382.9
	2	550.9	292.0	495.8	607.7	465.4
Oilmeal	1	493.4	268.2	396.4	484.8	422.4
Oats	1	....	10.0	26.0	10.0	....
Alfalfa hay	1	402.0	157.0	258.0	126.0	222.0
	2	1050.0	691.5	1053.0	1009.5	1017.0
	3	568.0	277.6	499.0	485.0	486.0
	4	529.0	204.4	465.0	382.0	441.0
	5	902.0	289.2	902.0	661.6	902.0
	6	140.0	78.0	260.0	240.0	230.0
Silage	1	1615.0	929.5	1080.0	1620.0	1800.0
	2	1558.0	1355.0	1794.5	2112.2	1800.0
	3	1266.0	1205.4	1785.0	1972.5	1800.0
	4	722.7	734.7	878.2	1235.0	1096.7
	5	659.5	610.9	978.5	1050.6	975.3
	6	163.3	252.0	563.0	787.6	574.6
Green alfalfa	1	1084.6	1150.9	1104.3	2113.7	1132.4
Green clover	1	187.5	135.0	190.8	297.4	190.1
Green corn	1	1180.8	816.0	1195.0	1914.0	1178.8

TABLE 13. AMOUNT OF FEED BY LOTS RECEIVED BY COWS NOS. 206, 304, 400, 303 and 211.

	Lot	No. 206	No. 304	No. 400	No. 303	No. 211
Corn (Lbs.)	1	1224.0	813.6	664.5	464.0	....
	2	62.9	62.3	45.7	57.1	....
	3	636.0	734.6	429.8	....	234.6
	4	....	17.7	....	....	438.8
Bran (Lbs.)	1	612.0	406.8	332.2	232.0	....
	2	31.4	31.1	22.8	28.6	....
	3	318.0	367.3	214.9	....	117.3
	4	....	8.8	....	....	219.4
Oilmeal (Lbs.)	1	345.4	238.8	189.7	116.0	....
	2	15.7	15.6	11.4	14.3	....
	3	119.6	148.3	83.9	....	58.6
	4	....	4.4	....	....	109.7
Alfalfa hay (Lbs.)	1	291.0	....	....	....	....
	2	1631.0	1159.5	1029.5	819.5	....
	3	110.0	85.0	80.0	100.0	....
	4	904.0	750.0	684.0	....	....
	5	2748.9	2585.2	2135.3	....	60.0
	6	....	227.0	95.1	....	1118.5
Silage (Lbs.)	1	2085.5	160.0	644.0	....	....
	2	1925.0	1387.0	1715.0	1289.0	....
	3	1640.0	1170.0	1435.0	1245.0	....
	4	1769.0	1308.0	1376.0	1075.0	....
	5	527.0	881.0	554.0	....	680.0
	6	....	644.0	226.4	....	4034.0

TABLE 14. YIELD AND AVERAGE COMPOSITION OF MILK BY 10-DAY PERIODS. COW NO. 206.

Period	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein (N x 6.38)	Per cent sugar	Per cent ash
1	217.4*	3.27	.47	3.03	4.25	....
2	402.6	3.71	.46	2.94	4.21	.907
3	427.3	3.55	.46	2.96	4.14	.758
4	432.8	3.31	.47	2.97	4.50	.781
5	409.2	3.30	.41	2.61	4.58	.755
6	372.6	3.26	.45	2.86	4.41	.748
7	445.4	3.35	.44	2.82	4.06	.737
8	403.3	3.44	.45	2.89	4.35	.827
9	427.5	3.60	.45	2.88	4.58	.745
10	403.1	3.60	.43	2.77	4.47	.719
11	412.8	3.56	.43	2.76	4.08	.731
12	410.0	3.95	.45	2.90	4.00	.732
13	360.0	3.80	.47	3.03	3.91	.711
14	377.4	3.80	.46	2.96	4.06	.735
15	372.1	3.70	.46	2.96	4.20	.727
16	349.0	3.81	.47	2.97	4.16	.713
17	343.2	3.56	.46	2.95	4.19	.739
18	331.1	3.86	.44	2.97	3.84	.722
19	326.4	3.55	.44	2.83	4.30	.741
20	330.6	3.10	.46	2.94	4.30	.773
21	356.3	2.70	.47	3.00	4.19	.774
22	331.9	2.81	.45	2.88	4.18	.746
23	293.1	2.65	.45	2.88	4.30	.705
24	325.0	2.87	.47	2.98	4.27	.709
25	313.7	2.91	.45	2.87	4.29	.724
26	297.3	3.49	.46	2.95	4.27	.709
27	257.1	3.40	.47	2.98	4.15	.723
28	279.5	3.33	.50	3.17	4.25	.716
29	282.2	3.14	.50	3.16	4.35	.717
30	269.3	2.93	.49	3.05	4.08	.759
31	245.7	3.16	.50	3.20	4.20	.699
32	234.4	3.39	.51	3.23	3.77	.741
33	188.8	3.21	.50	3.20	3.70	.749
34	202.8	3.22	.51	3.26	3.49	.746
35	197.8	3.57	.51	3.26	3.53	.726
36	169.9	3.93	51	3.26	2.82	.758
37	188.0	3.52	.49	3.15	4.14	.729
Average		3.401	.463	2.951	4.175	.745

* 5 Days.

TABLE 15. YIELD AND AVERAGE COMPOSITION OF MILK BY 10-DAY PERIODS. COW NO. 304.

Period	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein N x 6.38	Per cent sugar	Per cent ash
1	366.8	4.18	.52	3.30	4.14	.761
2	389.2	4.00	.48	3.07	4.25	.762
3	397.6	4.10	.50	3.21	4.60	.726
4	388.2	3.95	.47	2.98	4.62	.709
5	344.9	3.48	.43	2.76	4.50	.748
6	326.5	3.59	.46	2.96	4.10	.690
7	336.9	3.69	.49	3.10	4.25	.711
8	322.1	3.80	.51	3.24	4.38	.731
9	260.3	4.10	.52	3.34	4.29	.730
10	276.8	3.43	.50	3.18	4.25	.726
11	264.2	3.90	.49	3.12	4.09	.729
12	261.5	3.60	.49	3.12	4.43	.716
13	268.0	3.55	.48	3.05	4.40	.713
14	271.6	3.50	.48	3.03	4.36	.760
15	275.8	3.44	.48	3.05	4.29	.759
16	282.5	3.46	.49	3.12	4.34	.724
17	263.3	3.45	.49	3.13	4.40	.719
18	253.4	3.49	.50	3.18	4.36	.708
19	262.2	3.36	.50	3.18	4.57	.670
20	262.9	3.42	.50	3.17	4.45	.710
21	260.4	3.50	.49	3.15	4.49	.719
22	246.3	4.01	.52	3.31	4.50	.682
23	262.6	3.96	.54	3.43	4.56	.707
24	242.4	4.00	.53	3.21	4.54	.694
25	233.9	3.70	.53	3.37	4.62	.699
26	225.4	4.02	.55	3.52	4.35	.747
27	215.8	3.96	.59	3.74	4.20	.751
28	180.8	4.18	.60	3.82	4.00	.748
29	173.7	4.10	.62	3.94	3.47	.700
30	145.8	4.65	.65	4.12	3.50	.764
31	141.3	4.71	.61	3.87	4.25	.740
32	132.6	5.07	.64	4.06	4.13	.769
33	132.0	5.01	.61	3.92	4.24	.778
34	143.4	4.26	.59	3.74	4.43	.737
35	142.3	4.31	.58	3.69	4.49	.769
36	137.2	4.48	.61	3.87	4.49	.739
37	78.4*	4.75	.58	3.71	4.50	.721
Average		3.853	.514	3.278	4.339	.725

* 4 Days.

TABLE 16. YIELD AND AVERAGE COMPOSITION OF MILK BY 10-DAY PERIODS. COW NO. 400

Period	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein N x 6.38	Per cent sugar	Per cent ash
1	105.7*	4.35	.61	3.86	4.68	.801
2	207.7	4.29	.56	3.59	4.80	.791
3	213.0	4.21	.57	3.65	4.62	.832
4	228.4	3.90	.54	3.48	4.70	.800
5	228.8	3.98	.56	3.59	4.70	.811
6	227.6	3.85	.56	3.58	4.80	.801
7	224.6	3.68	.56	3.55	5.00	.817
8	225.5	3.42	.55	3.52	3.50	.795
9	220.1	3.90	.53	3.38	4.09	.806
10	207.3	3.75	.56	3.57	4.60	.765
11	199.5	4.10	.56	3.59	4.60	.766
12	199.2	3.80	.54	3.45	4.56	.767
13	192.9	3.75	.55	3.53	4.66	.769
14	190.2	3.80	.54	3.42	4.27	.781
15	177.3	3.94	.51	3.28	4.58	.762
16	164.2	4.10	.53	3.37	4.92	.763
17	163.9	3.44	.51	3.28	4.65	.773
18	166.4	3.45	.53	3.36	4.48	.744
19	155.1	3.65	.52	3.33	4.67	.763
20	166.5	3.70	.53	3.40	4.65	.760
21	163.0	3.70	.53	3.39	4.70	.745
22	158.6	3.65	.54	3.42	4.74	.749
23	156.7	3.61	.54	3.41	4.75	.743
24	142.5	4.06	.53	3.38	4.75	.738
25	142.4	3.92	.55	3.52	4.72	.748
26	134.2	4.17	.55	3.51	4.75	.783
27	114.7	3.81	.55	3.51	4.30	.791
28	93.7	4.27	.56	3.59	4.10	.799
29	96.2	3.65	.57	3.62	4.02	.778
30	80.9	4.20	.55	3.52	4.00	.806
31	74.2	4.28	.57	3.61	3.60	.799
32	71.4	4.23	.56	3.56	3.02	.789
33	60.6	4.20	.55	3.53	2.15	.793
34	57.4	4.70	.56	3.55	4.25	.785
35	56.2	4.54	.56	3.55	4.33	.807
36	51.1	4.39	.55	3.49	4.50	.792
37	55.3	4.22	.55	3.51	4.51	.789
Average		3.889	.547	3.491	4.498	.781

* 5 Days.

TABLE 17. YIELD AND AVERAGE COMPOSITION OF MILK BY 30-DAY PERIODS. COW NO. 43.

30 days ending	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein (N x 6.38)	Per cent sugar	Per cent ash
Oct. 25	920.5[1]	4.60	.57	3.64	5.30	.710
Nov. 24	776.4	5.18	.59	3.76	5.45	.770
Dec. 24	680.0	5.42	.55	3.51	4.50	.747
Jan. 23	674.8	5.15	.52	3.32	4.55	.615
Feb. 22	652.5	5.35	.56	3.57	3.70	.707
Mar. 23	669.5	5.02	.55	3.51	4.10	.712
Apr. 22	634.9	5.20	.55	3.51	4.35	.720
May 22	615.6	5.03	.53	3.38	4.60	.728
June 21	586.8	4.80	.56	3.57	4.00	.697
July 21	619.0	4.20	.55	3.51	4.78	.664
Aug. 20	599.7	4.20	.57	3.64	4.49	.697
Sep. 23	509.8[2]	4.30	.59	3.76	3.89	.609
	8039.5	4.88	.56	3.56	4.52	.70

[1] 32 Days.
[2] 34 Days.

TABLE 18. YIELD AND AVERAGE COMPOSITION OF MILK BY 30-DAY PERIODS. COW NO. 4.

30 days ending	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein (N x 6.38)	Per cent sugar	Per cent ash
Nov. 24	1266.4[1]	5.18	.63	4.02	4.97	.842
Dec. 24	631.5	5.67	.64	4.08	3.83	.768
Jan. 23	643.6	5.80	.62	3.96	.....	.800
Feb. 22	623.2	5.95	.62	3.96	4.00	.760
Mar. 23	622.4	5.97	.65	4.15	4.20	.791
Apr. 22	524.3	6.10	.63	4.02	4.70	.792
May 22	454.3	5.72	.66	4.21	4.60	.702
June 21	454.7	5.40	.67	4.27	4.10	.661
July 21	489.9	5.17	.64	4.08	4.41	.737
Aug. 20	475.5	4.67	.65	4.15	4.36	.684
Sep. 19	426.1	5.00	.68	4.34	4.16	.732
Oct. 5	161.7[2]	5.20	.70	4.47	4.36	.731
	6773.6	5.50	.64	4.12	4.28	.76

[1] 48 Days.
[2] 16 Days.

TABLE 19. YIELD AND AVERAGE COMPOSITION OF MILK BY 30-DAY PERIODS. COW NO. 63.

30 days ending	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein (N x 6.38)	Per cent sugar	Per cent ash
Oct. 25	500.2[1]	5.90	.69	4.40	4.70	.778
Nov. 24	641.4	6.22	.72	4.59	3.83	.780
Dec. 24	579.0	6.50	.69	4.40	......	.741
Jan. 23	563.3	6.40	.67	4.27	4.08	.740
Feb. 22	523.6	6.43	.70	4.47	4.35	.741
Mar. 23	520.9	6.35	.70	4.47	4.60	.771
Apr. 22	590.0	6.60	.70	4.47	5.05	.795
May 22	463.3	6.28	.68	4.34	4.50	.744
June 21	470.6	5.77	.65	4.15	4.40	.713
July 21	419.9	5.57	.68	4.34	4.10	.707
Aug 20	420.1	5.20	.66	4.21	4.53	.684
Sep. 19	323.0	5.40	.69	4.40	3.66	.703
Oct. 2	118.6[2]	5.56	.67	4.27	4.28	.696
	6033.9	6.09	.68	4.37	4.21	.74

[1] 22 Days.
[2] 13 Days.

TABLE 20. YIELD AND AVERAGE COMPOSITION OF MILK BY 10 DAY PERIODS. COW NO. 303.

Period	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein (N x 6.38)	Per cent sugar	Per cent ash
1	294.9	3.73	.48	3.09	4.75	.725
2	307.5	3.75	.49	3.12	4.76	.716
3	302.9	3.62	.50	3.18	5.00	.691
4	293.4	3.56	.48	3.06	5.02	.726
5	297.2	3.97	.48	3.04	4.78	.752
6	297.2	3.86	.48	3.04	4.56	.708
7	284.3	3.78	.48	3.05	4.62	.733
8	270.8	4.10	.48	3.05	4.56	.665
9	264.3	4.13	.47	2.97	4.51	.682
10	254.2	4.04	.46	2.92	4.63	.649
11	239.9	4.02	.47	2.97	4.75	.720
12	218.5	3.89	.46	2.92	4.25	.654
Average		3.861	.476	3.040	4.695	.703

TABLE 21. YIELD AND AVERAGE COMPOSITION OF MILK BY 10-DAY PERIODS. COW NO. 211.

Period	Pounds milk	Per cent fat	Per cent nitrogen	Per cent protein (N x 6.38)	Per cent sugar	Per cent ash
1	395.8	3.16	.47	3.02	4.57	.681
2	386.3	2.91	.45	2.89	4.72	.708
3	371.4	2.96	.43	2.71	4.80	.674
4	379.9	3.03	.44	2.83	4.82	.678
5	403.5	3.18	.44	2.82	4.86	.680
6	418.7	3.15	.45	2.84	4.95	.666
7	423.5	3.13	.45	2.87	5.05	.651
8	415.1	3.07	.46	2.96	5.05	.657
9	408.7	3.00	.45	2.89	5.05	.653
10	392.7	3.02	.45	2.89	5.09	.657
11	387.8	3.02	.45	2.89	5.08	.658
Average		3.052	.446	2.868	4.904	.667

TABLE 22. SUMMARY OF MILK YIELDS AND AVERAGE COMPOSITION.

Cow No.	Breed	Pounds milk	Per cent fat	Per cent protein	Per cent sugar	Per cent ash
206	Holstein	11,986.9	3.40	2.95	4.18	.75
304	Ayrshire	9,169.0	3.85	3.28	4.34	.73
400	Shorthorn	5,573.0	3.89	3.49	4.50	.78
43	Jersey	8,039.5	4.88	3.56	4.52	.70
62	Jersey	3,188.9	5.31	3.99	4.52	.75
4	Jersey	6,773.6	5.50	4.12	4.28	.76
27	Jersey	8,522.9	5.51	3.98	4.60	.73
63	Jersey	6,033.9	6.09	4.37	4.21	.74
303	Ayrshire	3,325.1	3.86	3.04	4.70	.70
211	Holstein	4,393.4	3.05	2.87	4.90	.67

TABLE 23. YIELD OF MILK, MILK CONSTITUENTS AND ENERGY VALUE OF MILK.

Cow No.	Pounds fat	Pounds protein	Pounds sugar	Energy value (therms)	Energy value per lb. milk (therms.)
206	407.7	353.8	499.9	3307.6	.2759
304	353.3	300.6	397.9	2789.4	.3042
400	216.9	194.5	250.7	1743.0	.3127
43	387.9	282.5	359.7	2830.7	.3520
62	169.4	127.3	144.4	1219.9	.3825
4	372.9	278.3	290.2	2630.3	.3883
27	470.0	339.4	392.6	3344.0	.3923
63	367.9	263.8	265.4	2536.1	.4203
303	128.4	101.1	156.1	1020.0	.3067
211	134.1	126.0	215.5	1200.8	.2733

MAINTENANCE

The results of the maintenance trials for the four Jersey cows, Nos. 27, 63, 43, 62 have already been published in detail[1] and will not be repeated here. Trials were conducted in a similar manner for Nos. 206, 304, 400. At the end of the year in milk these cows were dryed as soon as possible and the maintenance trial begun about one month later or as soon as the ration could be properly adjusted to the smaller requirements. With all seven animals the ration used on maintenance was the same and consisted of the same feeds as fed when in milk. The grain was a mixture of corn meal, 4 parts, wheat bran, 2 parts and linseed oilmeal, 1 part. The ratio between the amounts of grain, hay and silage fed, was 1:1:4.

No. 206 was a large framed cow carrying but little flesh. The results seem to indicate that a cow of this type requires somewhat more than the Armsby standard for maintenance while a cow carrying more flesh is liable to come close to this standard. Probably had No. 206 carried 100 lbs. more flesh her maintenance requirement would have been closer to the standard. Such an addition to a cow of this size would not have increased the body surface to any extent and would not have been sufficient to have burdened the organs of the body.

No. 206 was started at an average weight of 1283 lbs. for the first 10 days, while the average for the last 10 days was 1303 lbs., a gain apparently of 20 lbs. in 150 days.

No. 400 averaged 1139 lbs. for the first ten days and closed at 1127 lbs., an apparent loss of 12 lbs. in 150 days. Her maintenance requirement was exceedingly close to Armsby's standard.

No. 304 average 990 lbs. for the first 10 days and 978 for the last 10, an apparent loss of 12 lbs. Her maintenance requirement was also almost exactly as called for by the standard used.

The data in Table 24 gives the average ration per day, for each of the seven cows for which maintenance trials were made, the requirement in energy value for an animal of that weight according to Armsby's standard and the energy value of the ration actually required as calculated by using Armsby's "Production Value" tables.

Table 25 gives the total amount of protein and energy value required for the entire maintenance period calculated by using Armsby's standard.

[1]Research Bulletin No. 5, Missouri Exp. Station.

TABLE 24. SUMMARY OF RATION FED ON MAINTENANCE.

Cow No.	Days on mainten-ance	Pounds grain per day	Pounds hay per day	Pounds silage per day	Weight of animal	Armsby standard (therms)	Actually used (therms)
206	150	4.48	4.48	17.94	1291	7.25	7.91
304	130	3.32	3.32	13.28	1984	5.90	5.86
400	150	3.77	3.77	15.06	1129	6.58	6.65
27	160	3.29	3.30	13.20	889	5.55	5.81
62	180	2.92	2.92	11.76	916	5.59	5.17
63	120	2.95	2.95	11.88	886	5.80	5.21
4	150	3.43	3.43	13.78	792	5.20	6.06

TABLE 25. TOTAL PROTEIN AND ENERGY REQUIRED FOR MAINTENANCE.*

Cow No.	Therms per day	Therms for entire period	Pounds protein per day	Pounds protein for entire period
206	7.25	2646.2	.61	222.7
304	5.90	2153.5	.49	178.9
400	6.58	2401.7	.56	204.4
43	5.19	1894.3	.42	153.3
62	5.59	2040.3	.46	167.9
4	5.20	1898.0	.43	157.0
27	5.55	2025.7	.46	167.9
63	5.80	2117.0	.48	175.2
303	6.10	732.0	.51	61.2
211	6.22	684.2	.52	57.2

* Calculated by using Armsby's Standard.

PROTEIN AND ENERGY USED FOR MILK PRODUCTION.

Comparison With Armsby's Standard. As previously stated no attempt is made in this investigation to determine the protein requirement for milk production. The general plan was to feed sufficient protein and study the requirement for energy value. Table 26 therefore is introduced to show how much protein was used per pound of milk by each cow with no intention of assuming it to be the proper amount. This table is calculated from the quantity of feed given each animal as found in Table 9, and by using Armsby's "Production Value" table which is of course based upon average composition of feedstuffs. Later in Table 38 another protein figure is given based upon actual analyses and digestion

TABLE 26. PROTEIN IN FEED FOR MAINTENANCE, FOR PRODUCTION, AND PER POUND OF MILK.

Cow No.	Total protein consumed Pounds	Total protein for maintenance Pounds	Protein available for production Pounds	Protein per pound of milk Pounds
206	824.9	222.7	602.3	.0502
304	687.7	178.9	508.8	.0554
400	543.3	204.4	338.9	.0608
43	708.1	153.3	554.8	.0690
62	402.1	167.9	234.2	.0734
4	662.0	157.0	505.0	.0745
27	713.1	167.9	545.2	.0640
63	655.2	175.2	480.0	.0795
303	193.4	61.2	132.2	.0397
211	249.7	57.2	192.5	.0438

coefficients. It will be observed that the amount of protein used by the cows No. 400, 304, and 303 that produced milk with a fat content of close to 4% was higher in two cases and lower in one than the amount suggested by Armsby. Since Armsby does not give the protein requirements for cows with milk richer than 4% the comparison cannot be carried farther.

The main comparison to be made is with the total energy value of the ration. Table 27 is calculated by using the amount of each feedstuff as given in Table 9 and the "Production Value" tables of

TABLE 27. ENERGY IN FEED FOR MAINTENANCE, FOR PRODUCTION, AND PER POUND OF MILK.

Cow No.	Energy value of feed (Therms)	Energy for maintenance (Therms)	Energy available for production (Therms)	Energy used per pound milk (Therms)
206	5823.6	2646.2	3177.4	.265
304	4733.2	2153.5	2579.7	.281
400	3882.9	2401.7	1481.2	.266
43	5159.1	1894.3	3264.8	.405
62	3139.4	2040.3	1099.1	.345
4	4968.9	1898.0	3070.9	.453
27	5598.3	2025.7	3572.6	.419
63	5036.1	2117.0	2919.1	.483
303	1605.5	732.0	873.5	.263
211	2079.7	684.2	1395.5	.317

Armsby. Since this table is based upon average analyses it means that in Table 27 no use is made of the actual chemical analyses which were made of all the feeds used. The "Production Value" table is used in this case as it is intended to be used by assuming all feeds to be of average composition.

The "energy for maintenance" is the amount that each animal would require for this purpose during the entire period in milk, assuming that their maintenance requirement was that of Armsby's standard for an animal of the respective weights as calculated in Table 24. The "energy available for production" is the difference between the total energy value of the ration and the amount needed for maintenance. The available energy value divided by the total pounds of milk produced by the animal gives the final figure, the energy value used per pound of milk. It will be observed that the requirement varies from .265 therms for No. 206 with an average fat content of 3.40, to .483 therms for No. 63 with 6.09% fat. The figures for No. 303 and 211, the two that were in the experiment for less than a year compare fairly well with the others except No. 211 is considerably higher than some others giving richer milk. These results will be discussed further in another connection but it is evident from the data given that the richness of the milk is an important factor in determining the amount of feed required and that the requirement varies quite consistently with the energy value of the milk.

Table 28 brings together for comparison the average per cent of fat for each cow, the energy required per pound of milk calculated as

TABLE 28. ENERGY VALUE OF FEED PER POUND OF MILK.*

Cow No.	Per cent fat in milk	Armsby's standard: Therms per pound of milk	Actual maintenance: Therms per pound of milk	Energy value per pound of milk (Therms)
206	3.40	.265	.245	.2759
304	3.85	.281	.283	.3042
400	3.89	.266	.261	.3127
43	4.88	.406	....	.3520
62	5.31	.345	.372	.3825
4	5.50	.453	.409	.3883
27	5.51	.419	.437	.3923
63	6.09	.483	.524	.4203
303	3.86	.263	....	.3067
211	3.05	.317	....	.2733

* Calculated by Armsby's Standard and Tables and by Actual Maintenance and Armsby's Tables.

in Table 27 and the energy required per pound of milk when the actual maintenance requirements are used in place of using Armsby's standard.

No. 206, for example, according to the Armsby standard should have a maintenance requirement of 7.25 therms per day while the result of the 150-day trial indicated that she used 7.91 therms. The latter figure is used in making the calculation given in the column headed "actual maintenance" in Table 28. The calculations are made by using the same "Production Value" figures. The figures obtained in this manner are necessarily more accurate since one varying factor, that of maintenance requirement, is eliminated by using the actual in place of the estimated.

The cows for which no figures are given in the column headed "Actual Maintenance" are those for which maintenance trials were not made. The energy required per pound of milk as calculated in this manner varies from the first calculation with certain animals and tends to make the results more consistent. For example No. 62 which shows a very low energy requirement per pound of milk calculated by using Armsby's standard for maintenance shows a considerably higher figure on account of having an exceedingly low maintenance figure. In general, the data presented shows that for those cows, No. 304, 400, 303, that produced milk containing close to 4% that the requirements were not far from the standard as suggested by Armsby. Three of these cows while producing milk showing between 3.80 and 3.90% fat used about .03 therms below Armsby's figures for milk with 4.0% fat. It should be borne in mind that these cows were farrow and kept at uniform weight, conditions that do not necessarily exist with many cows in ordinary dairy herds. Armsby gives no figures for the requirements of cows producing above 4% fat, therefore no comparison can be made of the energy used by the cows producing the richer milk.

COMPARISON WITH HAECKER'S STANDARD.

Table 29 gives the amount of digestible protein, carbohydrates and fat that each cow would require per pound of milk according to Haecker's standard. The column headed "Total Nutrients" is introduced to combine the nutrients so a comparison may be made with the amount actually received. In calculating these figures the digestible ether extract was multiplied by 2.25 and the result added to the digestible protein and carbohydrates.

TABLE 29. NUTRIENTS REQUIRED FOR MILK BY HAECKER'S STANDARD.*

Cow No	Per cent fat	Protein	Carbo-hydrates	Ether extract	Total Nutrients
206	3.40	.043	.194	.015	.271
304	3.85	.046	.210	.016	.292
400	3.80	.046	.210	.016	.292
43	4.88	.053	.243	.018	.337
62	5.31	.056	.256	.019	.355
4	5.50	.057	.263	.019	.363
27	5.51	.057	.263	.019	.363
63	6.09	.061	.283	.021	.391
303	3.86	.046	.210	.016	.292
211	3.05	.040	.184	.014	.256

* Maintenance calculated by Haecker's Standard.

Table 30 is calculated to show the nutrients actually used by the cows in this experiment. In making these calculations the total digestible nutrients were found by applying to the feed received the figures from the tables found in Henry's "Feeds and Feeding."

TABLE. 30. NUTRIENTS USED FOR MILK PRODUCTION.

Cow No.	Protein	Carbo-hydrates	Ether extract	Total nutrients	Haecker's mainten-ance. Percent above standard	Actual mainten-ance. Percent above standard
206	.068	.152	.015	.254	—6.3	+11.0
304	.077	.189	.016	.302	+3.4	+19.8
400	.086	.105	.019	.234	—19.9	+17.5
43	.093	.296	.023	.441	+30.8	....
62	.099	.119	.034	.295	—16.9	+27.8
4	.103	.325	.026	.589	+62.2	+33.3
27	.086	.292	.024	.432	+19.0	+23.1
63	.108	.319	.029	.492	+25.8	+55.2
303	.053	.154	.016	.243	—16.8	....
211	.059	.219	.017	.316	+23.4	....

The amount to be deducted for maintenance was determined by using Haecker's standard of digestible nutrients, namely, protein, .7 lbs., carbohydrates, 7.0 lbs., ether extract, .1 lb. per 1000 lbs. live weight. It is impossible to compare the different nutrients di-

rectly to any advantage since the cows in this trial received so much more protein in their ration. The only comparison of much significance is between the columns giving total nutrients. The column next to the last in this table gives the per cent of total nutrients above or below that called for by Haecker's standard for a cow giving milk of this particular richness. It will be observed that five out of the eight cows whose records cover the entire year used more nutrients than Haecker's standard calls for. In one case the excess was 62.2%. Three of the eight cows used less than Haecker's standard calls for. Of the two cows used for shorter intervals one used less and one more than the standard. Only one of the cows producing milk with over 4% of fat was able to do so with the nutrients called for by this standard. The last column is calculated by using the actual maintenance requirements as found for the animals for which the figures are given. The average amount of grain, hay and silage fed as given in Table 24 was used with the same figures as before for calculating the digestible nutrients. The results calculated in this way are far more consistent. In every case the cows used more than the amount prescribed by Haecker's standards. It should be further noted that this excess is greater with the richer milk. At a later point data is introduced for two Jersey cows producing milk testing from 6.47% to 7.27% fat and covering a period of 142 days. One producing 2238 lbs. of milk with a fat content of 7.27%, used nutrients to the amount of 27.2% above the standard. The other producing 1942 lbs. milk with 6.47% fat used 10.2% excess of nutrients. Maintenance was assumed to be as calculated from Haecker's standard.

The only conclusion that can be drawn from the data given is that Haecker's standard did not, for these cows, supply sufficient nutrients for milk production and maintenance. The deficiency was most marked with those cows producing rich milk. Haecker's experiments upon which he based his standard covered 154 days, during the winter season. Only two cows were included that produced milk with a fat content above 5% and these were not far in excess of that figure. He assumed average maintenance requirements. His low results may have come about from having used cows with maintenance requirements below the average which would tend to lower the amount used per pound of milk produced. It is also possible that his cows were underfed but the time was not sufficient to make the condition noticeable.

REQUIREMENTS FOR PRODUCTION

As already indicated all feeds given were subjected to chemical analyses. The results of these analyses together with the amount of each lot consumed by each cow during the production period are found in Tables 10, 11, 12 and 13.

Results of Digestion Trials. A digestion trial was also conducted with five of the animals, namely, No. 206, 304, 400, 62 and 27, covering 10 days when near the maximum milk production, and again for each of the same animals when dry and on a maintenance ration. This data for Nos. 27 and 62[1] has already been published. As a result of this work it has been found that each of the five animals showed a digestion coefficient when on full feed that was considerably lower than the average digestion coefficients in common use. In making these calculations the figures given by Jordan[2] found in Table 31 were taken as average digestion coefficients. In Table 32 the lines headed "Average" give the digestion coefficient for each cow calculated for each constituent of the ration using the chemical analyses and the average digestion coefficients. The lines marked "Actual" give the per cent of that constituent of the ration as actually digested according to the results of the 10-day trial.

It will be observed that in only a single case was the digestion of any of the constituents equal to what it should be calculated by average figures generally used. It should be said further that the

TABLE 31. AVERAGE DIGESTION COEFFICIENTS USED.

	Protein	Crude fibre	Nitrogen-free extract	Ether extract
Corn	67.9	58.0	94.6	92.1
Bran	77.8	28.6	69.4	68.0
Oilmeal	88.8	57.0	77.6	88.6
Alfalfa	72.0	46.0	69.2	51.0
Silage	49.3	66.7	68.6	80.0
Green alfalfa	74.0	43.0	72.0	39.0
Green Corn	54.0	51.0	75.0	78.0
Green Clover	66.0	49.0	71.0	61.0
Oats	77.0	31.0	77.0	89.0

[1]Research Bulletin No. 4, Missouri Exp. Station.
[2]Jordan, W. H., The Feeding of Animals.

TABLE 32. COMPARISON OF AVERAGE AND ACTUAL DIGESTION COEFFICIENTS. FULL RATION.

	Cow No. 206. Holstein	Cow No. 400. Shorthorn	Cow No. 304. Ayrshire	Cow No. 27. Jersey	Cow No. 62. Jersey
Total dry matter					
Average	70.46	70.19	71.78	70.81	70.79
Actual	65.34	65.52	64.31	66.27	66.95
Protein					
Average	69.52	68.68	70.82	70.20	70.20
Actual	62.48	61.30	61.57	58.75	60.58
Crude fibre					
Average	55.47	56.46	54.62	53.90	53.90
Actual	50.41	50.94	47.48	53.82	53.89
Nitrogen free extract					
Average	75.57	75.04	77.08	76.60	76.60
Actual	72.54	72.28	71.39	72.62	73.62
Ether extract					
Average	70.44	70.79	72.11	78.00	78.00
Actual	68.72	71.80	72.00	66.95	59.82

same cows on maintenance showed a digestion coefficient even higher than average figures as may be seen from Table 37. The next step was to calculate the actual digestion coefficients in per cent of the average coefficients. The results of this calculation are given in Table 33. For example, No. 27 according to this could be assumed

TABLE 33. ACTUAL DIGESTION COEFFICIENTS EXPRESSED IN PER CENT OF AVERAGE COEFFICIENTS.

Cow No.	Protein	Crude fibre	Nitrogen-free extract	Ether extract
27	83.69	100.00	94.84	85.83
62	86.30	100.00	96.11	76.69
206	89.88	90.88	95.98	97.56
304	86.96	86.93	92.63	100.00
400	89.69	90.21	96.32	101.42

to digest 83.69% as much protein as would be found by using average digestion coefficients. In this way a table of digestion coefficients for each feedstuff was calculated for each of the animals

TABLE 34. DIGESTION COEFFICIENTS AS CALCULATED FOR COW No. 27.

	Protein	Crude fibre	Nitrogen-free extract	Ether extract
Corn	56.80	58.00	89.70	79.00
Bran	65.10	28.60	65.80	58.40
Oilmeal	74.30	57.00	73.60	76.00
Alfalfa hay	60.30	40.00	65.60	43.80
Silage	41.30	66.70	65.00	68.70
Green alfalfa	61.90	43.00	68.30	33.50
Green corn	45.20	51.00	71.10	67.00
Green clover	55.20	49.00	67.30	52.40
Oats	64.40	31.00	73.00	76.40

used. Table 34 gives this data for No. 27. It has to be assumed in doing this that since No. 27 digested only 83.69% of the protein from the total ration that she should have done by average figures, that the digestion coefficient for the protein was depressed an equal amount for the protein in each part of the ration. Since the rations fed were kept in nearly the same proportions as between the grain and roughness this assumption would seem to be one that could be made without serious error. The digestion coefficients were calculated for each of the other animals in precisely the same manner but these figures are not put in print. Since no digestion trials were made for Nos. 63, 4, 43, 211, 303, the coefficients used for calculating the results from these animals are the averages of those for the five animals, Nos. 206, 304, 400, 27, 62.

Table 35 gives this data in detail as calculated for No. 27. The others were prepared in the same manner but it was not thought necessary to put these figures into print in detail as they can be calculated by anyone interested from the data given. The summary is found in Table 38.

Calculation of Energy Value. The calculations based upon the chemical analyses and the digestion trials were made for each animal separately and were conducted as follows: The total amount of each constituent, as for example protein fed in the form of corn, was determined from the tables giving the record of feed consumed (Tables 1, 8) and from the record of chemical analyses (Tables 10, 12). The next step was to apply the digestion coefficient as calculated for the particular cow from the digestion trial (Table 34). This gives the amount of each digestible nutrient as far as could be calculated

TABLE 35. DIGESTIBLE NUTRIENTS AND ENERGY VALUES IN MILK DURING YEAR. COW NO. 27.

Feed	Digestible Nutrients			Total crude fibre	Digestible albuminoids	Energy value (Th'rms)
	Protein (Lbs.)	Carbohydrates (Lbs.)	Ether extract (Lbs.)			
Corn	94.5	1266.0	75.9	35.5	83.2	1636.6
Bran	93.3	373.4	35.4	88.3	75.5	437.4
Oilmeal	123.8	152.1	24.8	38.7	121.0	336.0
Alfalfa hay	252.5	1130.9	31.0	911.9	164.8	879.2
Silage	76.3	1332.3	60.1	561.9	47.4	1340.9
Green alfalfa	60.6	204.6	2.9	153.6	31.3	194.8
Green clover	8.7	54.3	1.3	32.8	6.1	50.3
Green corn	20.1	280.0	12.1	135.8	6.9	276.6
Oats	.7	4.7	.4	1.1	.6	6.2
Total	730.5	4798.3	243.9	1959.6	536.8	5158.0

for the animal in question. The amount of digestible albuminoids and the energy value in therms was calculated according to the method followed by Armsby in the calculation of his "Production Value" tables.[1] Under the head "Digestible Albuminoids" is included the digestible proteins minus the protein in the amide form. The amides are assumed to be entirely digestible. The percentage of "amides" assumed for the different feeds were as follows:

Corn.......... .58 per cent	Silage........... .33 per cent
Bran..........1.80 per cent	Green clover.... .86 per cent
Oilmeal........ .58 per cent	Green corn...... .69 per cent
Alfalfa hay...3.02 per cent	Green alfalfa...1.39 per cent

The first four analyses of the feedstuffs used, were made by T. E. Woodward by the use of Stutzer's reagent. The figures used for the other feedstuffs were calculated from Farmers' Bulletins 22 and 346. The digestible protein (albuminoids) as given by Armsby in Bulletin 346 is subtracted from the digestible protein in Bulletin 22. The difference represents the amides. The total digestible albuminoids received by each cow is also given in Table 38.

Maintenance. The calculations for maintenance were based upon the chemical analyses of the feed and the digestion coefficients as calculated for the individual animals. Complete data regarding the maintenance trials for Nos. 27, 62, 4 and 63 are already in print.

[1]Armsby, Bulletin 71, Pa. Exp. Station.

The composition of the ration fed 206, 304 and 400 may be calculated by taking the amount fed per day from Table 24 and using the chemical analyses as given in Table 36. Table 37 is made up in the

TABLE 36. COMPOSITION OF FEED GIVEN COWS NOS. 206, 400 AND 304 ON MAINTENANCE.

	Percent protein	Percent crude fibre	Percent nitrogen free extract	Percent ether extract	Percent ash
Corn	9.33	1.88	73.68	2.76	2.40
Bran	16.73	9.80	51.20	5.16	6.40
Oilmeal	31.46	7.57	35.65	9.91	5.76
Alfalfa	13.08	26.90	38.47	3.03	7.78
Silage	2.81	6.12	17.81	0.34	2.12

TABLE 37. COMPARISON OF AVERAGE AND ACTUAL DIGESTION COEFFICIENTS ON MAINTENANCE.

	Cow No. 206 Holstein	Cow No. 400. Shorthorn	Cow No. 304. Ayrshire	Cow No. 27. Jersey	Cow No. 62. Jersey
Total dry matter					
Average	65.3	65.3	65.3	69.1	69.7
Actual	70.5	69.9	69.6	73.8	72.2
Protein					
Average	69.1	69.0	69.2	69.4	68.7
Actual	71.1	69.7	73.5	67.3	65.5
Crude fibre					
Average	56.3	56.3	56.2	52.7	53.8
Actual	67.8	62.8	63.4	55.3	52.1
Nitrogen free extract					
Average	75.5	75.5	75.6	74.6	75.4
Actual	79.9	77.7	79.1	82.1	81.0
Ether extract					
Average	71.8	71.8	71.9	77.0	76.7
Actual	75.7	75.1	78.1	73.2	73.9

same form as Table 32. The figures in the lines headed "Average" represent the per cent of the ration that should be digested calculated from average digestion coefficients as given in Table 31. The figures in the lines headed "Actual" show the amounts

digested as found by the digestion trial. From this data a table of digestion coefficients on maintenance was calculated for each animal as explained for Table 34. From these tables the data was calculated which appears under the heads of maintenance in Table 38. The digestible albuminoids and the energy value were calculated as explained in the paragraph, "Calculations of Energy Value," p..—

Table 38 gives the total digestible protein, carbohydrates and ether extract calculated as explained by using the chemical analyses of the feed consumed and the digestion coefficients as calculated for each cow from the digestion trials. The digestion coefficients used for Nos. 4 and 63, however, are the averages for the five for which digestion trials were made. The maintenance data was not taken for No. 43 and for this reason only the therms for maintenance are included which are calculated from the averages of the others.

TABLE 38. NUTRIENTS AND ENERGY FOR MILK PRODUCTION.

	Digestible nutrients			Digestible albuminoids	Energy value (Therms)
	Protein	Carbohydrates	Ether extract		
Cow No. 206					
Total consumed.......	1005.0	5278.4	273.2	775.8	5956.5
For maintenance......	442.3	2845.5	109.1	355.5	3133.9
For milk (11,986 lbs.).	562.7	2432.9	164.1	420.3	2822.6
For 1 pound milk, 3.40 percent fat..	.0469	.203	.0136	.035	.235
Cow No. 304					
Total consumed ...	807.5	4044.2	229.9	617.7	4426.2
For maintenance....	337.6	2060.4	83.2	273.8	2287.1
For milk (9169) lbs..	469.9	1983.8	146.7	343.9	2139.1
For 1 pound milk, 3.85 percent fat..	.051	.216	.016	.0375	.233
Cow No. 400					
Total consumed.....	675.3	3555.9	186.6	515.4	3885.0
For maintenance....	361.4	2301.7	88.7	289.1	2528.0
For milk (5573 lbs.)	313.9	1254.2	97.9	226.3	1357.0
For 1 pound milk, 3.89 percent fat..	.056	.225	.0175	.0406	.243
Cow No. 43					
Total consumed.....	760.5	4372.9	267.9	575.2	4822.0
For maintenance....	....	....	....	....	1894.3
For milk (8039 lbs.).	....	....	....	....	2927.7
For 1 pound milk, 4.88 percent fat..	....	....	....	....	.364

TABLE 38. NUTRIENTS AND ENERGY FOR MILK PRODUCTION. (Continued.)

	Digestible Nutrients			Digestible albuminoids	Energy value Therms
	Protein	Carbo-hydrates	Ether extract		
Cow No. 62					
Total consumed.....	421.2	2719.8	119.7	312.4	2884.4
For maintenance....	267.9	1832.3	99.3	211.7	2002.8
For milk (3188 lbs.)	153.3	887.5	20.4	100.7	881.6
For 1 pound milk, 5.31 percent fat..	.048	.278	.006	.032	.276
Cow No. 4					
Total consumed.....	708.7	4318.2	257.6	528.7	4695.9
For maintenance....	309.5	2173.2	118.3	243.5	2387.0
For milk (6773 lbs.).	399.2	2145.0	139.3	285.2	2313.9
For 1 pound milk, 5.50 percent fat..	.0587	.3167	.0205	.042	.3416
Cow No. 27					
Total consumed.....	730.5	4798.3	243.9	536.8	5158.0
For maintenance....	298.6	2128.0	115.0	235.4	2330.5
For milk (8522 lbs.).	431.9	2670.3	128.9	301.4	2827.5
For 1 pound milk, 5.51p ercent fat..	.051	.313	.015	.035	.332
Cow No. 63					
Total consumed.....	707.6	4324.0	258.8	528.2	4700.3
For maintenance....	270.8	1865.5	99.3	213.8	2036.7
For milk (6033 lbs.).	436.8	2458.5	159.5	314.4	2663.6
For 1 pound milk, 6.09 percent fat..	.072	.4075	.026	.052	.4415

Energy Used for Production. The energy required per pound milk calculated from the chemical analyses and the digestion trials is lower than that given in Table 27 where the calculations were based upon Armsby's standard for maintenance and his "Production Value" tables used to estimate the amount of energy value contained in the ration. The figures also are lower than those found in Table 28 where actual maintenance was deducted and the "Production Value" tables used to calculate the value of the ration consumed. One reason why the requirements, as calculated in Table 38, are lower is that the cows in every case did not digest as high a proportion of the ration as is represented by average digestion coefficients which are made the basis of Armsby's "Production Value" tables while on maintenance the same cows digested fully as much

as indicated by average digestion coefficients. The results of this is to decrease the apparent requirements in the way of energy value. It should be pointed out in this connection that the digestion trial carried out when the cows were in milk was made at the maximum production and since the digestion coefficient was increased when the cows were dry and on a low ration as needed for maintenance it is probable that during that part of the milking period when the production of milk was low the digestion coefficient was really higher than the one calculated. For this reason it is probable that the requirements given per pound of milk in Table 38 is really a little too low. It is recognized that the data given in Table 38 offers little that can be made use of at present in practical feeding operations.

Do Production Value Tables Apply to Milk Production? The author believes that the data presented justifies the question being raised as to the accuracy of the "Production Value" tables as prepared by Kellner and Armsby when applied to milk production. Kellner used mature fattening oxen in his investigation, and the "Production Value" tables of Armsby are based upon these results. Armsby states that practically no experiments of similar character are available for other purposes of feeding. Another point indicating that there is a discrepancy somewhere is the fact that the energy value of the milk (Table 23), with one exception, and that the cow with the richest milk is actually higher than the energy value of the feed necessary to produce it. (Table 38.) If the energy value of the feed is calculated directly by Armsby's "Production Value" tables(Table 28) six out of ten cows show more energy in the milk than in the feed. It would appear more probable that the error is in the energy value used for the feed than in the figure used for the energy value of the milk solids which presumably has been determined with reasonable accuracy. The author believes the data presented for the seven cows that were in the investigation during an entire year and for which maintenance trials were afterwards conducted is as accurate as can be taken by the means of investigation at hand. To carry the problem of the production value of feeds when used for milk production to a solution will probably require an extensive series of investigations by the use of a calorimeter with cows in milk.

DATA FROM OTHER SOURCES.

The data as presented shows that the energy requirements for very rich milk is higher in proportion to the energy value of the milk than is the requirement for milk poorer in fat. The figure for No.

63 with an average of 6.09% fat is especially high. The following data is introduced for further comparison regarding the requirements for rich milk. Accurate feed and milk records are at hand for two Jersey cows in the University herd, but no maintenance data for these cows is available. This data is given in Table 39. The calculations are all made by using Armsby's "Production Value" tables and his maintenance standard. During this period the weights of the cows remained practically constant although both were pregnant. The energy per pound of milk is high with both. Cow No. 50 with 7.27% fat is practically the same as No. 63 reported in Table 28 that produced milk with 6.09% fat. No. 55 with a fat content of 6.47% is lower than No. 63. This bears out in general the accuracy of the data from No. 63 covering the full year but suggests the possibility that No. 63 for some reason required rather more than the average for this richness of milk.

TABLE 39. FEED AND PRODUCTION OF TWO JERSEY COWS FOR 142 DAYS.

	Cow No. 50	Cow No. 55
Alfalfa hay	956 lbs.	877 lbs.
Clover hay	378 lbs.	362 lbs.
Cowpea hay	90 lbs.	90 lbs.
Silage	3629 lbs.	3203 lbs.
Grain	1003 lbs.	730 lbs.
Weight of cow	898 lbs.	823 lbs.
Total energy in ration	1860.3 therms	1668.1 therms
Energy for maintenance	792.4 therms	782.6 therms
Energy for milk	1067.9 therms	891.4 therms
Milk produced	2238.6 lbs.	1942.6 lbs.
Average percent fat	7.27 percent	6.47 percent
Energy per pound milk	.477 therms	.458 therms

Table 40 gives results taken from the work of Savage,[1] Most of his cows made decided gains in weight and for that reason only those were selected that remained practically uniform in weight during the 142 days of the experiment. In general his figures which are likewise calculated by using Armsby's "Production Value" tables and maintenance standard, show somewhat lower range than those reported in Table 28.

[1]Savage, E. S., Bulletin 323, Cornell University Exp. Station.

TABLE 40. REQUIREMENTS FOR MILK PRODUCTION—CORNELL UNIVERSITY HERD.

Name	Breed	Pounds milk per day	Average per cent fat	Energy per pound milk (Therms)
Hector's Buta	Jersey	23.49	5.53	.368
Cornella	Jersey	18.49	5.31	.376
Cornella	Jersey	24.12	5.28	.305
Effie	Guernsey	18.58	4.66	.333
Sigma	Holstein	35.81	3.93	.281
Charity	Holstein	31.82	3.73	.285
Omega	Holstein	25.91	3.72	.353
Psi	Holstein	23.98	3.46	.281
Chi	Holstein	27.66	3.44	.306
Eta	Holstein	36.25	3.22	.262

Relation of Richness of Milk to Economy of Fat Production. Table 41 gives the total energy in therms used by each cow per pound of fat, also the energy in therms per pound of fat after deducting maintenance. In calculating the energy available for milk production, the actual maintenance requirements as given in Table 24 are used. For No. 43, 303 and 211, for which no maintenance data was taken, it is assumed that their maintenance requirements were those called for by Armsby's standard. The total energy value of the feed is taken from Table 27. This data shows that the cheapest production of fat is with heavy producing cows, such as No. 27, that secrete milk with a high per cent of fat. This corroborates the general data along this line which indicates that cows of those breeds having a high fat content are on the average slightly more economical producers of fat. Table 41 also exhibits the well-known facts that a high production of fat is an economical one from the standpoint of feed consumed. No. 27 used 11.91 therms per pound fat while No. 62 used 18.53 therms. No. 304 produced 353 pounds of fat and used total energy to the amount of 13.4 therms per pound fat. No. 400, producing milk of similar richness but only 217 pounds in quantity, used 17.9 therms per pound fat. The last column is significant. It shows the energy required per pound of fat after deducting maintenance. It should be kept in mind that the data for Nos. 303 and 211, both of which exhibit wide variations, covers only 110 and 120 days respectively and that their maintenance is estimated. Leaving these out the data on the others shows a striking uniformity. The energy per pound of fat is less in every case for those animals producing the milk lower in per cent of fat. The Jerseys with the

high fat content used more energy, varying from 7.39 to 8.53. The highest again is for the richest milk. The closeness of the results from No. 62 and No. 27 is striking in view of the wide variation in production. This fact has already been pointed out in another connection.[1]

TABLE 41. ENERGY REQUIRED PER POUND FAT.

Cow No.	Total energy in feed Therms	Fat produced (Pounds)	Total energy per pound fat (Therms)	Energy available for production (Therms)	Available energy per pound fat (Therms)
206	5823.6	407.7	14.28	2936.4	7.20
304	4733.2	353.3	13.40	2594.3	7.34
400	3882.9	216.9	17.90	1455.6	6.71
43	5159.1	387.9	13.30	3264.8	8.42
62	3139.4	169.4	18.53	1252.3	7.39
4	4968.9	372.9	13.32	2757.0	7.39
27	5598.3	470.0	11.91	3477.6	7.40
63	5036.1	367.9	13.69	3134.4	8.52
303	1605.5	128.4	12.50	873.5	6.80
211	2079.7	134.1	15.50	1395.5	10.40

The usual explanation of the more economical production of fat by Jerseys and Guernseys has been the fact that milk of these breeds contains more fat in proportion to the other milk constituents. The data presented strongly suggests another explanation. It is shown conclusively that after maintenance is deducted cows of the Jersey breed use more, rather than less energy value per pound of fat, and per therm of energy in the milk solids. This means that the difference is with the maintenance. The Jersey cows in our investigation, and the same would be true for the breed as a whole, produced more fat in proportion to their size than did the Shorthorn or Holstein. The food of maintenance therefore per unit of butterfat produced is less than with the other breeds which makes production of fat more economical on the basis of the total feed required. This is shown clearly by the following:

	Pounds fat	Average Weight	Maintenance therms	Per cent of ration for Maintenance.	Total Energy per pound fat.
No. 206........	407.7	1319	2887.2	49.5	14.28
No. 27.........	470.0	899	2120.7	37.8	11.91

[1]Research Bulletin No. 2, Missouri Exp. Station.

The total energy per pound of fat is, in this case, less for No. 27 with the greater fat production and smaller maintenance. At the same time No. 206 used her feed available above maintenance slightly more economically than did No. 27.

Relation of Richness of Milk to Economy of Production of Total Solids. It has been generally assumed that cows producing rich milk produce fat more economically and the data given indicates there is some basis for this belief although the advantage in favor of the rich milk is small. The data at hand also admits of a study of the relation of the energy in available feed to the energy value of the total solids produced in the milk. Table 42 indicates this relation. The comparison is made of the available energy, found as for Table 41, and expressing the relation of this energy to that of the milk produced.

These figures show, with the exception of No. 211, on experiment for a short period, that the highest ratio is with the milk containing the least fat. In other words a therm of energy in the feed produced more energy in milk when the per cent of fat was low than when it was high. Apparently a given amount of feed is most efficient when used to produce milk medium to low in fat. It appears from this that the production of fat is a greater tax upon the animal than is the production of other constituents of the milk carrying equal energy value.

TABLE 42. RATIO OF ENERGY IN FEED TO ENERGY IN MILK

Cow No.	In feed (Therms)	In milk (Therms)
206	1.00	1.126
304	1.00	1.075
400	1.00	1.197
43	1.00	0.867
62	1.00	0.974
4	1.00	0.954
27	1.00	0.961
63	1.00	0.809
303	1.00	1.167
211	1.00	0.851

A Tentative Statement of the Requirements for Milk Production. It is evident that the data is not at hand to make it possible to give an accurate statement regarding the requirements for milk production. Before this is possible it will apparently be necessary to revise the figures in use as digestion coefficients since it is evident

that the cow in milk falls considerably short of these figures which have been determined for animals on maintenance. Further, the production values for feed when used for milk production will have to be determined as it seems reasonably certain that the data along this line from experiments with fattening cattle are hardly applicable to dairy cows. The best that can be done at present is to express the requirements for milk production on the most accurate basis so far formulated which the author believes is Armsby's "Production Value" tables. In the suggested standard which is given below the energy requirement for 4.0% milk is that given by Armsby since it is borne out by our experimental results. The variation with the richness of the milk is based upon our data which has been given. The figure for digestible protein which in this case is albuminoids is based upon the standard of Armsby, the work of Savage and data obtained at this station. The experience of skillful feeders alone is sufficient evidence that a very high protein content is necessary for the sustained production of rich milk.

SUGGESTED STANDARD FOR COWS YIELDING MILK OF VARYING RICHNESS.

Per cent fat.	Digestible protein per pound milk.	Energy Therms per pound Milk
3.00	.050	.26
3.50	.052	.28
4.00	.055	.30
4.50	.058	.33
5.00	.062	.36
5.50	.066	.40
6.00	.070	.45
6.50	.075	.50

The following is suggested for herd feeding where it is not practical to take into account the richness of the milk of each individual.

	Digestible protein.	Energy therms
Holstein	.05	.26-.28
Shorthorn, Ayrshire, Brown Swiss	.055	.28-.30
Jerseys and Guernseys	.066	.40-.45

SUMMARY

The object of the investigation was to secure data regarding the requirements for milk production by cows yielding milk of varying richness. Data is presented giving the feed consumed with chemical analyses, and of milk produced with analyses for eight cows for an entire year. The milk of these cows ranged from 3.4% to 6.09% fat. Data of two other cows is included for shorter periods. These cows were all fed a ration of practically the same composition. The quantity fed was regulated so as to maintain a uniform weight.

All cows were kept farrow. A maintenance trial was made for seven cows using the same ration as fed when in milk. A ten-day digestion trial was made for five of these when at maximum milk production and again when on maintenance. The digestible protein and the energy value of the rations received are calculated according to Armsby's "Production Value" tables and also from the actual digestion coefficients. Comparison is made with Armsby's standard of energy required for milk of corresponding richness. The relation of the richness of the milk to the economy of fat production and to total energy in milk is also pointed out.

CONCLUSIONS.

The data bears out the results of others that more energy value is required in the ration for rich milk than for milk lower in fat.

The maintenance requirements for the seven cows showed some variation but was close to Armsby's standard for cows of the same weight.

The protein fed was in excess of that called for in the standard of Armsby or Haecker but no attempt was made to determine the minimum requirement.

When the energy value of the ration, in excess of maintenance, was calculated by the use of "Production Value" tables it was found that the cow producing milk with 3.4% fat used .245 therms per pound while one with milk averaging 6.09% fat used .524 therms per pound.

When Haecker's maintenance requirement was used and the amount of "digestible nutrients" calculated by using Henry's tables it was found that six cows used more than Haecker's standard and four less. When actual maintenance was deducted every cow used nutrients in excess of this standard. The deficiency increased with the richness of the milk. Four Jersey cows required from 23.1%

to 55.2% more nutrients than called for by Haecker's standard. This standard is clearly too low for cows with rich milk.

According to average digestion coefficients the five cows should have digested 70.8% of the ration received during the digestion trial when in milk. The results showed only slight variation with individuals and an average of 65.57% digested. On maintenance the same cows should have digested 66.69% of the ration received according to average figures but the results were higher in every case and showed an average of 71.2%.

A calculation based upon the chemical analyses of the feed and the actual digestion coefficients showed the actual energy value used in the feed per pound of milk was lower than indicated by applying Armsby's "Production Value" tables directly to the ration received. The cow producing milk with 3.4% fat actually used only .235 therms per pound milk while for 6.09% fat the requirement was .442 therms.

The total energy required in the feed was slightly less per pound fat produced in the richer milk. However, after subtracting maintenance the energy per pound fat is consistently higher for the richer milk.

The cheaper production of fat in the richer milk is shown to be due to a smaller maintenance requirement per unit of fat on account of the smaller size of the animals producing the richer milk.

The energy value of the milk solids is greater in proportion to the energy value of the feed required with the milk lower in fat. This indicates the production of rich milk requires an increase in feed in excess of the increase in energy value of the milk.

The cow is able to utilize energy in her ration to better advantage than is indicated by Armsby's "Production Value" tables which are based upon experiments with mature fattening animals.

A tentative standard is given of energy value and protein for cows producing milk from 3% to 6.5% fat.

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